

FINAL REPORT

Wide Area UXO Screening with the Multi-Sensor Fixed-Wing Airborne System MARS

ESTCP Project MM-0607

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ACRONYMS

3D	Three-Dimensional
AGL	Above Ground Level
AVR	Advanced Virtual RISC (Reduced Instruction Set Computer)
ASR	Archive Search Report
cm	centimeter
CSM	Conceptual Site Model
CTAF	Common Traffic Advisory Frequency
DAS	Data Acquisition System
DEM	Digital Elevation Model
DGM	Digital Geophysical Mapping
DoD	Department of Defense
DOP	Dilution of Precision
EM	Electromagnetic
EPA	Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
FAA	Federal Aviation Administration
FUDS	Formerly Used Defense Sites
GIS	Geographic Information Systems
GPS	Global Positioning System
HAE	Height Above Ellipsoid
HASP	Health and Safety Plan
HE	High Explosive
HeliMag	Helicopter Magnetometry
Hz	Hertz
IT	Information Technology
KAFB	Kirtland Air Force Base
KPBR	Kirtland Precision Bombing Range
lb	pound
LiDAR	Light Detection and Ranging
LSA	Light Sport Aircraft
m	meter
MAG	Magnetic
MARS	Minimum Altitude Remote Sensing
MEC	Munitions and Explosives of Concern
mm	millimeter
m/s	meters per second
MTADS	Multi-Towed Array Detection System
NDIA	New Demolitions Impact Area
NMEA GJK	National Marine Electronics Association time, position, position type, and DOP designation
NOTAM	Notice To Airmen
NRL	Naval Research Laboratory
nT	nanotesla
OB/OD	Open Burn/Open Detonation

Pd	Probability of Detection
Pfa	Probability of False Alarm
PI	Principal Investigator
PPS	Pulse Per Second
RMSE	Root Mean Square Error
RTK GPS	Real-time Kinematic Global Positioning System
SKY	Sky Research, Inc.
SORT	Simulated Oil Refinery Target
SW	Short Wing
UNICOM	Universal Integrated Communication
US	United States
USACE	US Army Corps of Engineers
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
WAA	Wide Area Assessment

1. INTRODUCTION

1.1 Background

This project is being conducted to demonstrate and certify a fixed-wing platform for deploying low altitude remote sensing technologies that can be used to help meet the increasing demand on the Department of Defense (DoD) for low-cost, high-resolution wide area assessment (WAA) of former and active military facilities contaminated with unexploded ordnance (UXO). The Minimum Altitude Remote Sensing (MARS) system can provide DoD the ability to characterize large sites cost efficiently, reliably, and safely. The MARS airborne UXO mapping system has been developed, successfully tested, and deployed in Europe by SeaTerra GmbH in Germany. Sky Research, Inc. (SKY) is demonstrating and certifying this system (Figure 1) for application in the United States (US) in partnership with SeaTerra.

The integration of proven geophysical sensor technologies, deployed at low altitudes using sophisticated, commercially available, off-the-shelf light sport aircraft (LSA) technology, represents a novel and innovative solution for DoD to successfully execute geophysical mapping and UXO characterization at large sites. This demonstration plan addresses the first phase of the technology demonstration, deployment of the LSA with magnetic (MAG) sensors; a separate demonstration plan will be submitted for the second phase of the project, which, if funded, will integrate electromagnetic (EM) sensors with magnetic sensors for concurrent data collection.

The first site selected for demonstration is the Former Kirtland Precision Bombing Range (KPBR) in order to provide the ability to compare performance, results and cost with another low altitude WAA technology, helicopter magnetometry (HeliMag). HeliMag was previously demonstrated at the site as part of the Environmental Security Technology Certification Program (ESTCP) WAA Pilot Program. In addition, the results of this demonstration will be integrated into the SKY WAA Geographic Information System (GIS) with the WAA data collected at the site (HeliMag, Light Detection and Ranging [LiDAR], orthophotography and ground based digital geophysical mapping [DGM] data) to facilitate data analysis, historical information integration, and data access.

The second demonstration site is at the Isleta Pueblo, New Mexico. The Pueblo is located approximately 13 miles south of Albuquerque. Data will be collected from a portion of Target S1, which was used for a 2003 ESTCP project where vehicular and airborne multi-towed array detection system (MTADS) data were collected. Data were collected and compared from one vehicular survey (used as a baseline) and two HeliMag systems as part of that project. In addition to comparison to the HeliMag and vehicular data from the 2003 surveys, the MARS data collected at Isleta Pueblo will provide a more comprehensive evaluation of the performance capabilities of the MARS system in a range of geologic and topographic conditions.

Some of the items detected during the 2003 survey at the Isleta site and the WAA survey at the Former KPBR were removed following the demonstrations. The locations of those excavated

items will be provided by ESTCP so they can be excluded from the comparison and scoring of the MARS system results.

Additionally, ESTCP will emplace test items within a designated area at the Former KPBR site. Some of the items will be used as a blind test to validate the system's performance, while the locations of other items will be disclosed and used for calibration.



Figure 1. The CT SW Light Sport Aircraft with magnetometer boom.

1.2 Objectives of the Demonstration

The principal objectives of this phase of the MARS project are to test and evaluate the MARS system in the US and compare the performance, results and cost to HeliMag technology. Similar to HeliMag, MARS is expected to demonstrate efficient low altitude digital geophysical mapping capabilities for metal detection at a resolution approaching that of ground survey methods, limited primarily by terrain, vegetation and topographic inhibitions to safe low altitude flight.

The capabilities that will be demonstrated as part of this phase of the project include:

1. A mobile, low-cost, high-resolution fixed-wing small aircraft survey system which is fully registered certified, tested, and demonstrated in the US;
2. Direct observation of surface and subsurface ferrous objects; and
3. Evaluation of target density distribution.

The second phase of the project would include combining MAG and EM sensors into one system and developing enhanced data fusion and interpretation software tools for processing the simultaneously recorded EM and MAG data.

1.3 Demonstration Sites

1.3.1 Former Kirtland Precision Bombing Range, NM

The Former KPBR is a WWII-era former military training facility located about 10 miles west of Albuquerque, New Mexico (Figure 2). Within the 15,246 acre Formerly Used Defense Site (FUDS), ESTCP established a 6,500 acre demonstration plan sub-area for the WAA Pilot Program. Results from the data analysis for the WAA Pilot Program confirmed the presence of three precision bombing targets (N2, N3 and New Demolitions Impact Area [NDIA]) and a simulated oil refinery target (SORT), and several additional areas of interest (also shown on Figure 2). For the current demonstration, the SKY/SeaTerra team will fly the MARS system over approximately 3,400 acres configured to encompass these targets. This acreage was also surveyed in the HeliMag demonstration conducted in 2005 which allows for a comprehensive comparison of the data collected using these two platforms.

The boundaries of the survey area cover an area with varying terrain and vegetation conditions to allow for evaluation of the performance of MARS under different settings. The exact area surveyed at the Former KPBR using the MARS system will be determined based on the pilot's and SKY field manager's on-site flight safety assessment of the site. The area estimated to be accessible assumes a 500 foot buffer around high-voltage power lines and other infrastructure and excludes areas within flight patterns for the Double Eagle Airport. Only the areas determined to be safely accessible for operating a low altitude fixed-wing aircraft will be flown.

1.3.2 Isleta Pueblo

The Isleta Pueblo is located approximately 13 miles south of Albuquerque (Figure 3). Target S1 comprises approximately 7,000 acres of land that was leased in the 1950s for use as a target bombing range for aircraft from Kirtland Air Force Base (KAFB). Documentation in Bureau of Indian Affairs files indicates that this area was used a practice bombing range from 1956 to 1961 to determine the performance of fast aircraft during bombing runs. In the 1960s, visible ordnance debris was collected and piled for removal. Up to 2 tons of practice bombs and ordnance waste per acre was removed, although no explosive ordnance was found. Target S1 was selected for the initial MTADS demonstration because it is of most concern to the tribe and has the greatest potential for high explosive (HE)-filled UXO. Approximately 1,250 acres of the area are proposed to be surveyed by the MARS system.

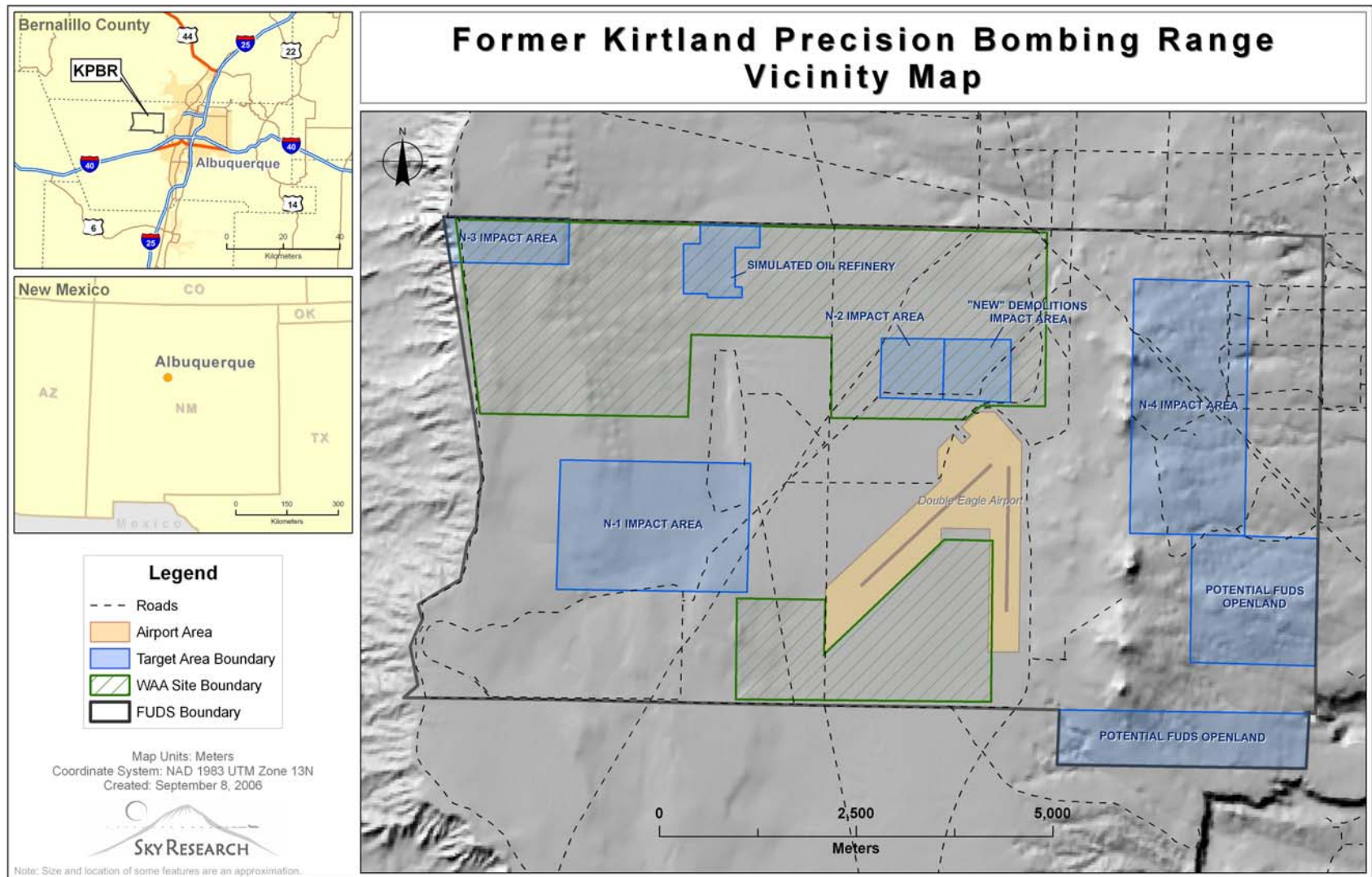


Figure 2. Former Kirtland Precision Bombing Range with identified bombing targets and other areas of interest.

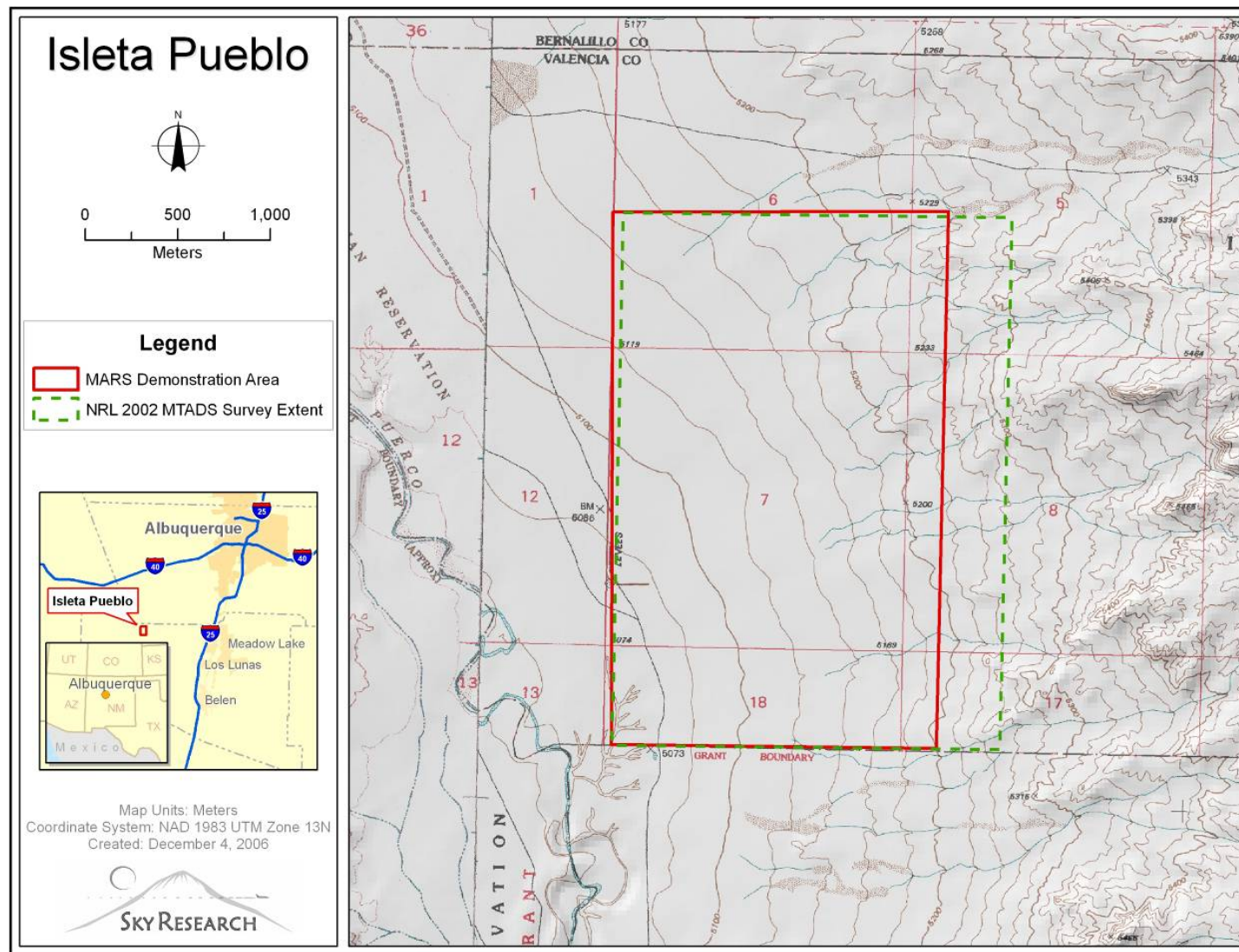


Figure 3. MARS demonstration site at Isleta Pueblo.

2. TECHNOLOGY DESCRIPTION

2.1 Technology Development and Application

SeaTerra GmbH, partnered with SKY for this project, has developed the MARS system. The system includes an array of magnetometers and software designed specifically to process data collected with this system and performs physics-based analyses on identified targets deployed on a low-cost, high-resolution, fixed-wing airborne system. The system has been used in Europe to survey nearly 8,000 survey acres. A summary of the previous application of the technology to munitions and explosives of concern (MEC) site characterization is provided in Section 2.2.

2.1.1 Airborne Platform

SKY has acquired the CT Short Wing (SW) model LSA for this demonstration. This model lightweight aircraft, a slightly different model aircraft than the one used by SeaTerra in Europe, will not affect the deployment of the technology. The aircraft has an 8.9 meter (m) wingspan, a length of 6.2 m, and can fly at a minimum height above ground of 2 m. It uses modern German glider structural design techniques and is essentially all-composite glass fiber reinforced plastic with very little ferrous metal and a low signature footprint. The aircraft serves as the platform for deployment of the sensor and positioning technologies used for this demonstration (Table 1).

Table 1. MARS Technology Components

Technology Component	Specifications
Geophysical Sensors	6 Geometrics G-822A cesium vapor magnetometers
GPS Equipment	Trimble AgGPS model 132 for Navigation and Trimble MS750 system with 2 GPS receivers for precise RTK positioning
Altimeters	1 Reigel Laser Altimeter
Inertial Measurement	SeaTerra compensation system
Magnetic compensation (and redundant attitude information)	SeaTerra digital compass and proprietary magnetic compensation system
Data Acquisition System and frequency counter	AGS MK3 (SeaTerra proprietary DAS and frequency counter): 0.1 nanotesla (nT) resolution at 200 Hertz (Hz): 0.1 to 0.25 nT noise floor
Aircraft	Flight Designs CT SW

2.1.2 Airborne Sensors and Boom

The airborne sensor boom houses an array of six Geometrics Model 822A cesium vapor magnetometer sensors evenly spaced at 1.25 to 1.4 m intervals in a magnetic sensor housing system (Figure 4). For this demonstration we will use 1.4 m sensor spacing. The sensor system is mounted on the CT SW (Figure 4) with support structures fixed to the aircraft wings. SeaTerra's AGS MK3 frequency counter and data acquisition system (DAS) will be used to record data at 200 Hz with an 0.1 to 0.25 nT noise floor. At a forward speed of 35 meters/second (68 knots) this will result in one measurement per 0.175 m. This system has been thoroughly tested on the MARS platform during field trials and production work within Germany.

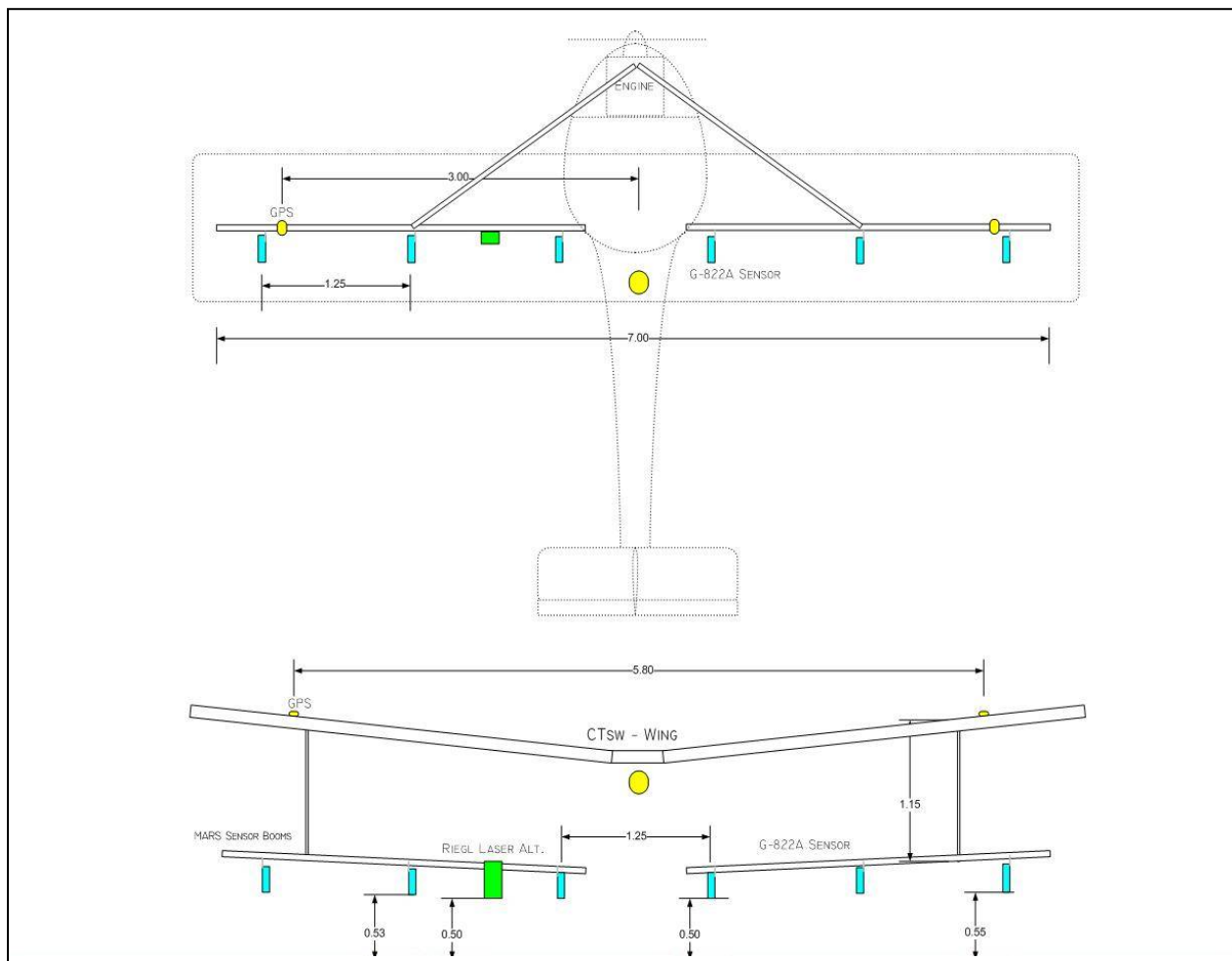


Figure 4. Schematic of the MARS sensor layout. In this configuration the sensors are 1.25 m apart. For this demonstration we will use 1.4 m sensor spacing.

2.1.3 Positioning Technologies

In the existing MARS system, the magnetometer data are positioned using a Trimble Ag model 132 global positioning system (GPS) that obtains differential corrections via an Omnistar satellite. This system can provide real-time sub-meter positions that can be post processed to obtain 50 centimeter (cm) accuracy.

For the system we deploy for this project we intend to use two Trimble MS750 GPS units configured in a Moving Base – Rover mode providing National Marine Electronics Association GGA (NMEA time, position, position type, and dilution of precision [DOP] designation) positions at 20 Hz GPS and Advanced Visual RISC [Reduced Instruction Set Computer] (AVR) orientation data at 10 Hz (this is the same system used successfully for the HeliMag). The system requires two MS750 Marine GPS receivers, two compact L1/L2 GPS antennas, 12-24 Volt power, and real-time kinematic (RTK) corrections. The GPS antennas will be flush-mounted close to the wing tips on both sides of the aircraft, in-line with the magnetometer boom. This will provide a baseline of 6 m. The NMEA GPS data provide the latitude and longitude of antennas while the AVR data return the platform roll and yaw. A 3-axis digital compass will measure the attitude information and in particular will provide the pitch of the system, which is the remaining piece of information needed to accurately position each sensor in 3-dimensional (3D) space (an equivalent concept is used very successfully in the HeliMag system).

A Reigel laser altimeter will record the aircraft height above ground at cm level accuracy at a sample rate of 50 Hz. Since the fixed-wing system does not change altitude quickly, the altitude values will have little variation. The normal flight height above ground is 2-3 m. The 3D position of each data point will be utilized in subsequent processing (e.g., the magnetic inversion modules in UXOLab allow inversion of magnetic data with variable altitudes).

Since both sites have been used for previous surveys, the existing surveyed points will be used to assure that geospatial data generated by the project is accurately tied to the local coordinate system.

2.1.4 Data Processing

The AG3 MK3 data acquisition system accurately time-stamps each of the sensor readings using an internal clock that is precisely synchronized to the 1 pulse-per-second (PPS) from the GPS. After the survey is complete the data are then processed as follows:

- The raw data for a given survey flight are time-aligned (e.g., the logged GPS times are corrected by reference to the PPS).
- Invalid data are rejected based upon status flags present in the raw data records (e.g., poor GPS fix) or, in the case of the magnetometer data, a simple ‘in range’ test may be used.
- Notch filters specifically designed to remove 60 Hz power-line interference and any harmonic noise from the aircraft are applied to the magnetometer data.

- The GPS geographic position coordinates are transformed to WGS84 Universal Transverse Mercator (UTM) coordinates.
- The GPS, magnetometer and auxiliary sensor data streams are then merged together using the time reference. Using knowledge of the sensor-GPS geometry each sensor is assigned a position and height above ellipsoid (HAE) based on the UTM location of the GPS receiver, the roll and yaw from the AVR and the pitch from the digital compass.
- To determine the height above ground, we will first use the laser altimeter data to build a digital elevation model (DEM) of the area. The DEM will be created by using the GPS location and the pitch, roll and yaw to determine the position and HAE of the laser reflection. The height above ground can then be simply obtained using the sensor HAE and the DEM.
- The magnetometer data are corrected for aircraft heading using the magnetic compensation system.
- The magnetometer data are filtered to remove geological and temporal trends.
- The notch filtered and detrended channels are gridded at 0.35 m pixel spacing.

Data processing rates are expected to be similar to HeliMag processing, where data collected over 300-500 acres can be processed in less than four hours to produce an initial image. This image is used to check survey coverage and operation of the system. If no problems are detected and the applied filters are appropriate, the image is used for data analysis as described in the section below. If filters are deemed inappropriate the filter parameters will be adjusted and the images recreated. A combination of SeaTerra's data processing software, UXO.NET and Geosoft Oasis Montaj will be used to implement the processing scheme outlined above.

2.1.5 Data Analysis

Anomalies will be selected once the magnetic anomaly maps are created. Automatic target selection for large scale surveys such as this one has the advantage of being objective and repeatable as well as much faster than manual target selection. Automatic target selection processes have been used for two WAA Pilot Program demonstration sites - Former KPBR and the Former Pueblo Precision Bombing Ranges, Colorado. However, automatic target pickers are not yet sophisticated enough to reliably detect closely spaced targets or targets that are at or below the same amplitude as local geologic signal, and are not able to differentiate between our targets of interest and local geologic anomalies. Therefore, automatic target selection routines must only be used to select targets with response amplitudes significantly above the nominal geologic noise, otherwise an inordinate number of false targets are selected. Furthermore, the automatic routines do not perform well in areas of high target density.

For the purposes of this project where the goal is to delineate target density throughout the survey site, the limitations of automatic target selection are not as detrimental as they would be if we were concerned with detecting every possible target. The challenge is to calibrate the automatic target selection routine so that the number of valid targets of interest selected is maximized, while minimizing the number of targets selected due to geologic noise or other noise

sources (geologic noise is usually the predominant noise source). To achieve this, manual target selection results will be compared with those obtained using an automated target selection routine over a representative subset of the survey site. The automatic selection process will utilize the Automated Wavelet Detection Algorithm (Billings, S.D., and F. Hermann, “Automatic detection of position and depth of potential UXO using a continuous wavelet transform”, in Proceedings of SPIE Vol. 5089, *Detection and Remediation Technologies for Mines and Minelike Targets VII*, pp 1012-1022, 2003).

Individual peaks in the magnetic data are followed across multiple scales, with the decay in peak amplitude related to the depth to the source. Nearby positive and negative peaks in the image are joined together if they have comparable depth estimates. In this way, incorrectly joining the peaks from nearby dipoles that are at different depths can be avoided. In the last stage of the algorithm, the amplitudes of the peaks and their relative position are used to provide an initial estimate of the dipole parameters. The detection thresholds will be chosen by reference to the data collected over the calibration line.

Filtered sensor data points will also be interpolated into magnitude surface rasters using GIS-based interpolation scripts. Target density distribution maps will then be directly compared with those prepared using the previously collected HeliMag data over the same areas.

To ensure that the target selection and density distribution analyses are unbiased, we will not use the same geophysicist to process the MARS data as was used to process the WAA data and the WAA data will be sequestered until these steps have been completed. Only when the analysis is complete and we are ready to begin the performance comparison using the HeliMag data will the processor have access to those data.

2.1.6 Geographic Information Systems

Following the target selection and density map preparation, the MARS data will be integrated with the WAA datasets collected as part of the WAA Pilot Program. The existing tools and data layers created for the geospatial demonstration for the WAA Pilot Program (ESTCP 0537) will be utilized for this project, with the MARS data added to the geospatial database for the site and the on-line data viewers.

2.2 Previous Testing of the Technologies

The MARS system has been tested by the German government on military ranges in southern Germany. In addition, over the last five years it has been used to conduct four commercial WAA UXO surveys covering nearly 8,000 acres in Germany (Table 2). Achieved productivity on these sites has ranged from 250-500 acres/day. The system has proven to be very accurate, efficient, reliable, and suitable even in areas that were considered non-ideal. The statistical approach of calculating relative density distribution coefficients has proven to be reliable and the results correlate with ground truth surveys and excavations. Since an array of cesium vapor magnetometers are the main detection sensors, the ability to detect small ferrous objects is

diminished as the separation between the sensor and the target increases. However, at 2 m elevation, MARS is capable of detecting 2.75” rockets and larger items of interest.

Table 2. MARS Survey Sites

German Training Range	Oversight	Total Area (acre)	Survey Area (acre)	Vegetation Condition	Topographic Relief	Facility Use
Münsingen	Government	16,055	3,952	40% Wooded	250 m	150 Years: Artillery, Infantry, Tank Training, Bombing
Eggersdorf	Private Investor	6,175	988	Free	0 m	100 Years: Military Airfield
Oranienburg	Government	2,470	494	50% Wooded	2 m	100 Years: Air Force Base
Trampe	German – EPA	14,820	1,976	30% Wooded	30 m	50 Years: Tank Training

In addition to the MARS testing and applications performed in Germany, test flights were performed in December 2006 to verify that the system acquired by SKY performs at least as well as the original SeaTerra system. In particular, the newer system is positioned using a dual RTK GPS Trimble system with centimeter-level position accuracy and accurate roll and yaw information. The initial testing of the system was conducted at the Ashland Airport in Ashland, Oregon, (Figure 5) using 6 sensors spaced 1.25 m apart. The following three tests were conducted:

- 1) **Noise and basic system test:** Static tests with engine off and with the engine running to characterize the major noise sources.
- 2) **High altitude heading and system noise test:** High altitude flight to determine the heading dependant effect of the aircraft on each sensor and to determine the sensor noise level while flying.
- 3) **Calibration flight and full system test:** Lower altitude flights over a test site located adjacent to the runway to at the Ashland Airport over calibration items and to test the full system. Test items included 5 inert 155 millimeter (mm) shells placed along the test flight pathway. In addition to the test items, 2 square wire loops of 0.5 m diameter were constructed and used to calibrate the positional and data integrity of the system. One coil was constructed such that it produce a 1 Am² current (10 turns of wire at ~0.4 A), and one with a current of 2 Am² (20 turns at ~0.4 A). These coils were precisely positioned using survey grade GPS with each coil horizontal so that it produced a vertical magnetic field.



Figure 5. Ashland Airport test site.

2.2.1 Noise and Basic System Test

The noise and basic system tests revealed a couple of minor issues with the location of the laser altimeter. In particular, its unshielded power cable ran quite close to sensor 3 and had to be moved. During noise tests with the motor running, the outer most sensors had very low noise (peak to peak < 0.5 nT), with the inner most sensors experiencing peak-to-peak noise of around 2.5 nT. We deferred detailed analysis of the sensor noise to the high altitude calibration flight, which is more representative of actual survey conditions.

2.2.2 High Altitude Heading and System Noise Test

An approximately 30 second section of data from the high altitude flight was chosen for detailed analysis of the noise characteristics of the sensors. During that 30 second duration, the plane maintained a straight flight path and did not traverse any areas with large changes in regional magnetic field. To remove any heading effects (as the plane changes its attitude slightly), a 0.5 second running mean was removed from the data. The resulting time-series and noise histograms are shown in Figures 6 and 7. The standard deviations of the noise in each sensor are provided in Table 3 and range from 0.1 nT in sensor 1 to 1.19 nT in sensor 3.

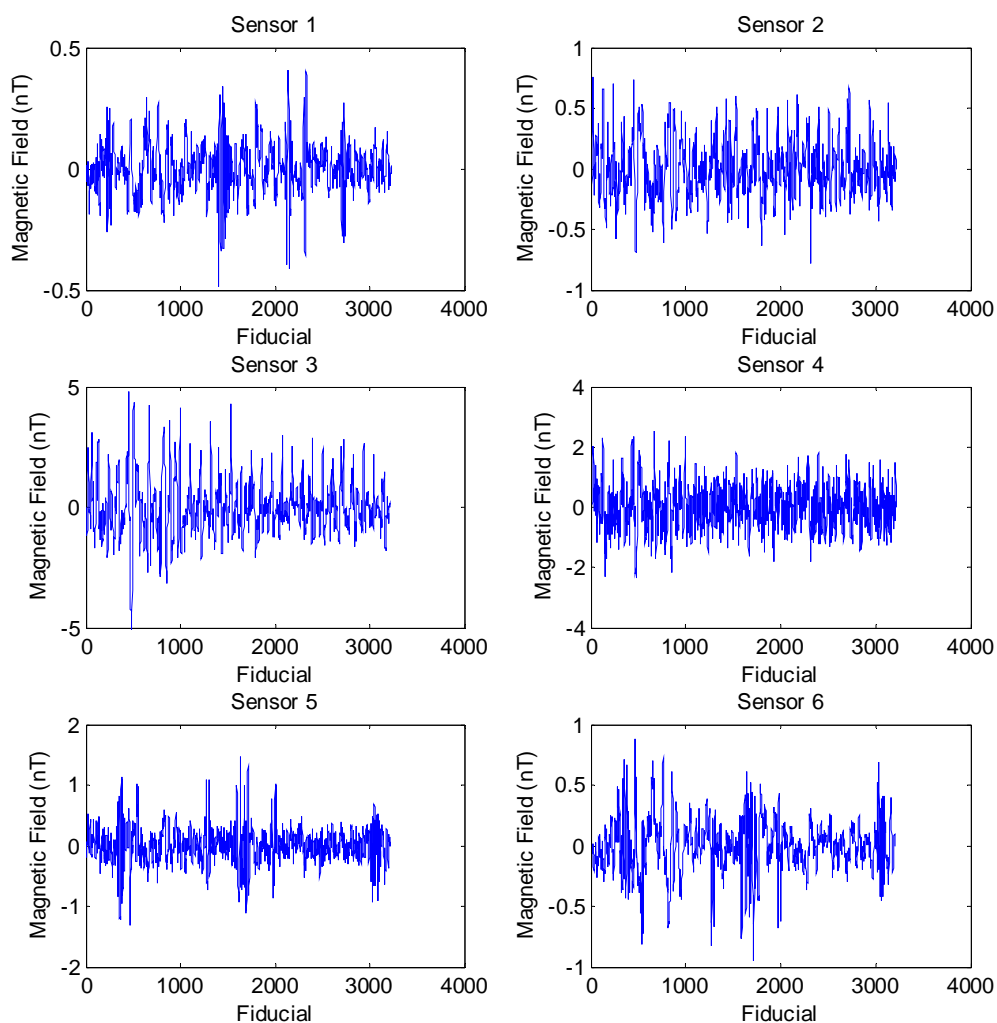
Power spectra of the time-series for each sensor are shown in Figure 8. There are significant spectral features centered at around both 8 and 9 Hz, with the relative importance of both dependent on the particular sensor. Notch filtering the data to remove these spectral features results in a slight reduction in the noise level (Table 3). However, the main spectral features are at lower frequencies and are more likely to correspond to changes in aircraft attitude rather than to noise from the aircraft engine and electrical system (see next paragraph).

Table 3 also lists the mean magnetic field of each sensor, as well as the differences in means between all sensors and sensor 1 (the left-hand, outermost sensor). There is over 850 nT difference between sensor 3 and sensor 1 which is due to the magnetization of the aircraft. As shown in Figure 9, this magnetization is attitude dependant. The figure plots the difference between the magnetic field at each sensor relative to sensor 1 as the aircraft executes a turn. For sensors 2, 5 and 6, there is at most a 150 nT variation in relative magnetic field. For sensor 3 the variation is around 700 nT and for sensor 4 it is 500 nT. These numbers indicate that there is a significant ferrous source near sensors 3 and 4.

The aircraft wheels are relatively close to sensors 3 and 4 and we had purposely replaced any ferrous metal components with stainless steel. Upon re-inspection of the wheels we discovered that the bolts in the wheel were ferrous metal and most likely causing the strong gradient in magnetic field. Following the test flights, we replaced the ferrous bolts with stainless steel bolts and also increased the distance between each sensor from 1.25 m to 1.4 m. We will conduct additional test flights the week before deployment to determine the impact of these changes on the sensor noise floor.

Table 3. Mean Magnetic Fields and Standard Deviations of the 30 Second High Altitude Section of Data

Sensor	Mean	Relative to sensor 1	Standard deviation Raw	Standard deviation Notched
Sensor 1	51445.1	0.0	0.10	0.10
Sensor 2	51413.2	-31.9	0.23	0.22
Sensor 3	50590.4	-854.7	1.19	1.17
Sensor 4	50747.2	-697.9	0.73	0.61
Sensor 5	51587.3	142.2	0.29	0.27
Sensor 6	51559.7	114.6	0.22	0.22

**Figure 6.** Thirty seconds of high altitude data from each sensor (at 100 Hz sampling). A 0.5 second running mean has been removed from each dataset.

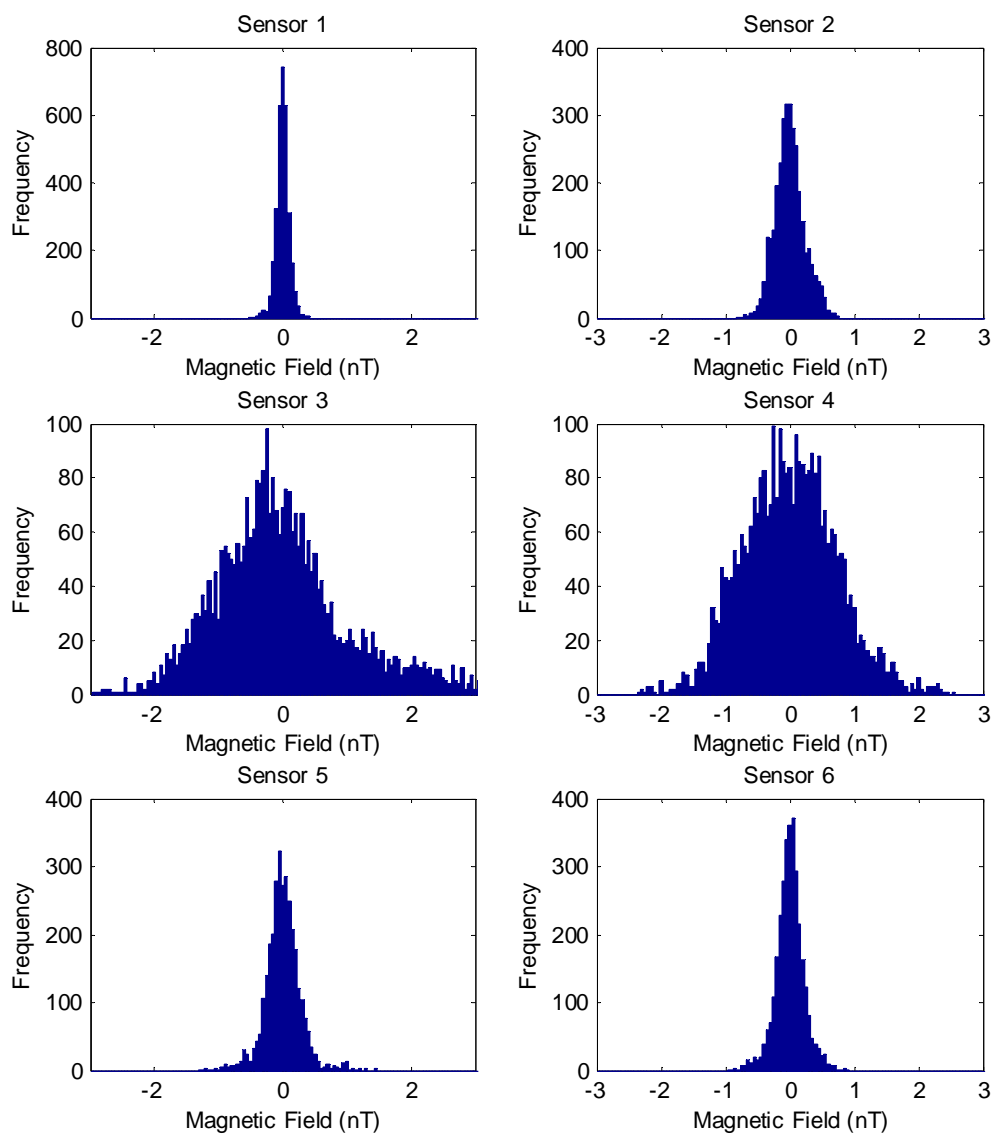


Figure 7. Noise histograms of the raw data from the high altitude test.

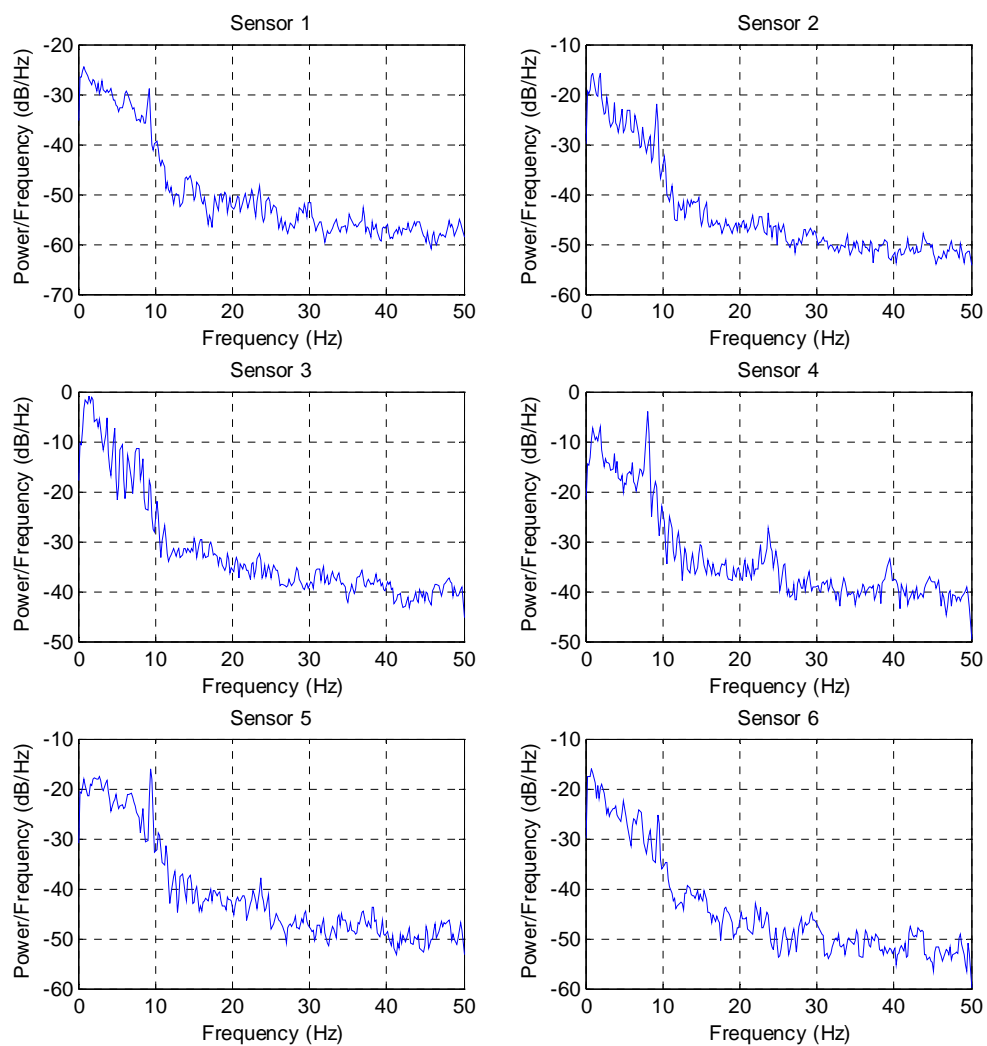


Figure 8. Power spectra of the high altitude data from each sensor.

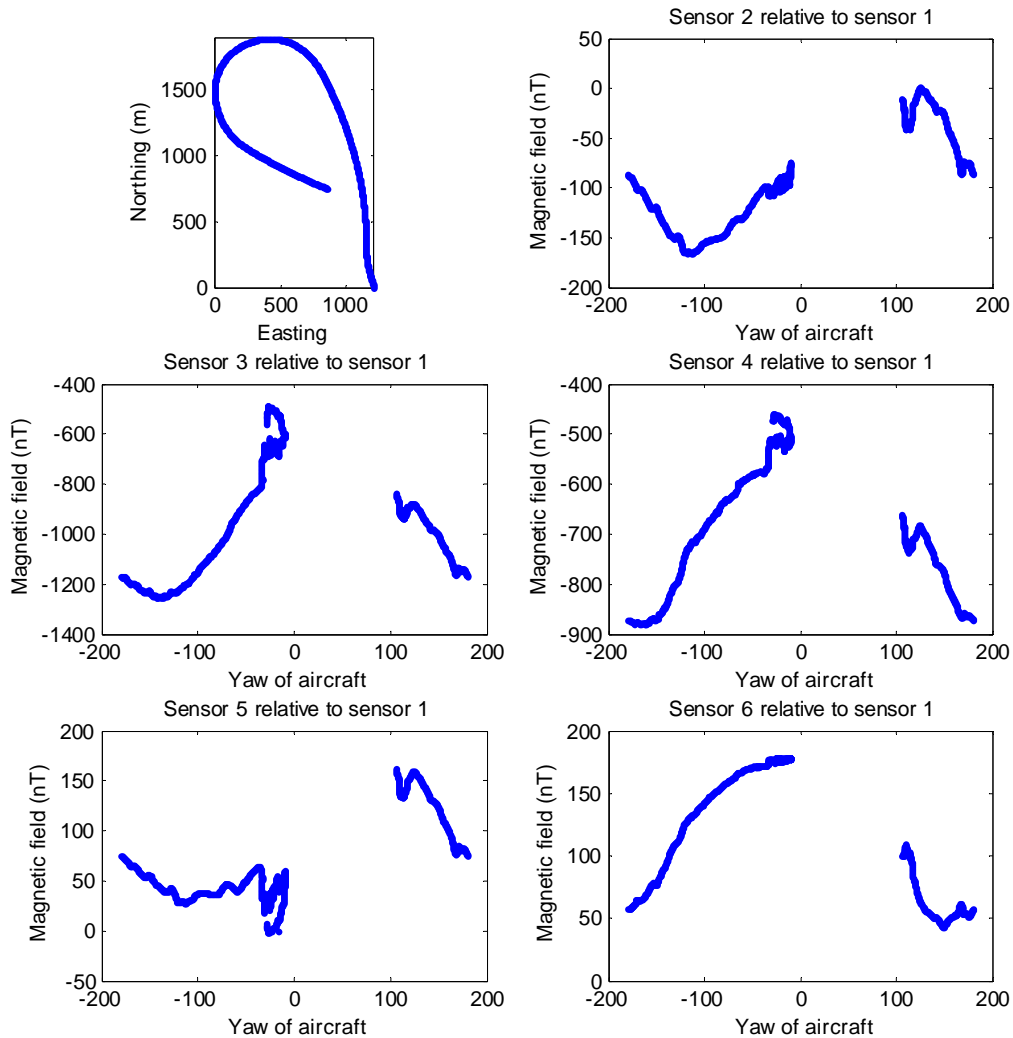


Figure 9. Magnetic field of each sensor relative to that of sensor 1, while executing the high altitude maneuver shown in the top left panel.

2.2.3 Calibration Flight and Full System Test

During the calibration flight a number of passes were made at altitudes of 10, 5 and 2 m. The higher altitudes were primarily conducted so that the pilot could become more familiar with the navigation system before flying close to the ground. At the lowest altitude, the pilot achieved a median height of 2.3 m with a minimum altitude of 1.25 m (Figure 10). The most northerly item (a 155 mm) was at the start of a depression and the pilot was typically pulling up to finish that line. Consequently, the sensors were never closer than 5 m to that item and it was not detected by the system. The other projectiles and two loops were all positioned to better than 40 cm (Table 4), with a mean positional error of 27 cm. Thus, the system is able to meet its performance objective of positioning to within 50 cm. The magnitude of the dipole moments of the calibration

loops were within 20% of the true value, while the orientation was recovered to within 27 degrees for the smaller one, and within 2.5 degrees for the larger.

Plots of the processed and modeled data for each of the detected seven calibration items are shown in Figures 11 (metallic targets) and Figure 12 (calibration loops) below. There is generally very good agreement between the processed data and the dipole fit, which further supports our conclusion that the system is performing as designed.

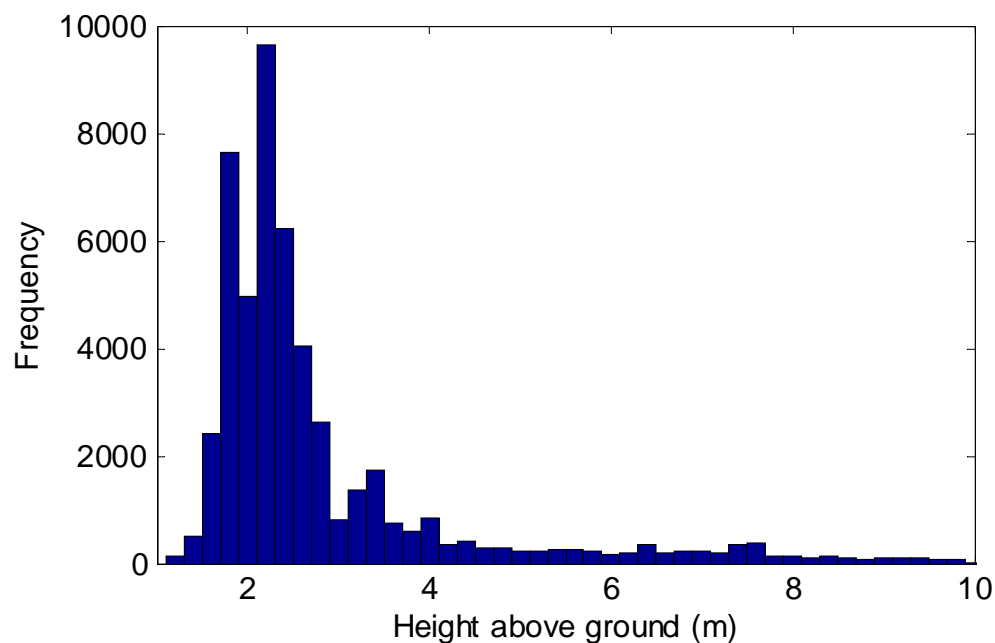


Figure 10. Histogram of the height above the ground during the three lowest level passes. Heights above 4 m typically occurred as the pilot pulled up at the end of the transect.

Table 4. Offset Between MARS Predicted Location and Surveyed Ground Truth Location

Target	Item Description	Easting (m)	East offset (m)	Northing (m)	North offset (m)	Offset (m)	Depth (m)	Amplitude (nT)	Moment (Am²)	Azimuth (degrees)	Azimuth	Dip
4003	155mm Projectile	528179.31	-0.35	4670808.64	-0.14	0.37	-0.09	31.9	2.8	44°	42.4	-29.8
4005	155mm Projectile	528083.565	-0.3	4670929.908	0.04	0.31	-0.03	16.7	0.9	89°	-48.3	-30.5
4007	155mm Projectile	528013.677	0.01	4671009.705	-0.3	0.3	0.34	166.4	6	324°	-10.7	-31.4
4009	155mm Projectile	527943.471	-0.09	4671100.163	-0.09	0.13	-0.04	34.9	2	93°	-77	-26.6
4011	155mm Projectile	527904.565	-0.19	4671149.365	0.2	0.27	0.43	66.4	6.7	325°	-35.9	-11.7
5001	Cal Loop 20 Turn West	528141.905	0.01	4670853.9	-0.28	0.28	-0.05	69.3	2.4	322°	4.9	73.1
5005	Cal Loop 10 Turn West	527977.349	0.05	4671055.639	0.2	0.2	-0.03	26.8	1.2	317°	-111.2	87.8

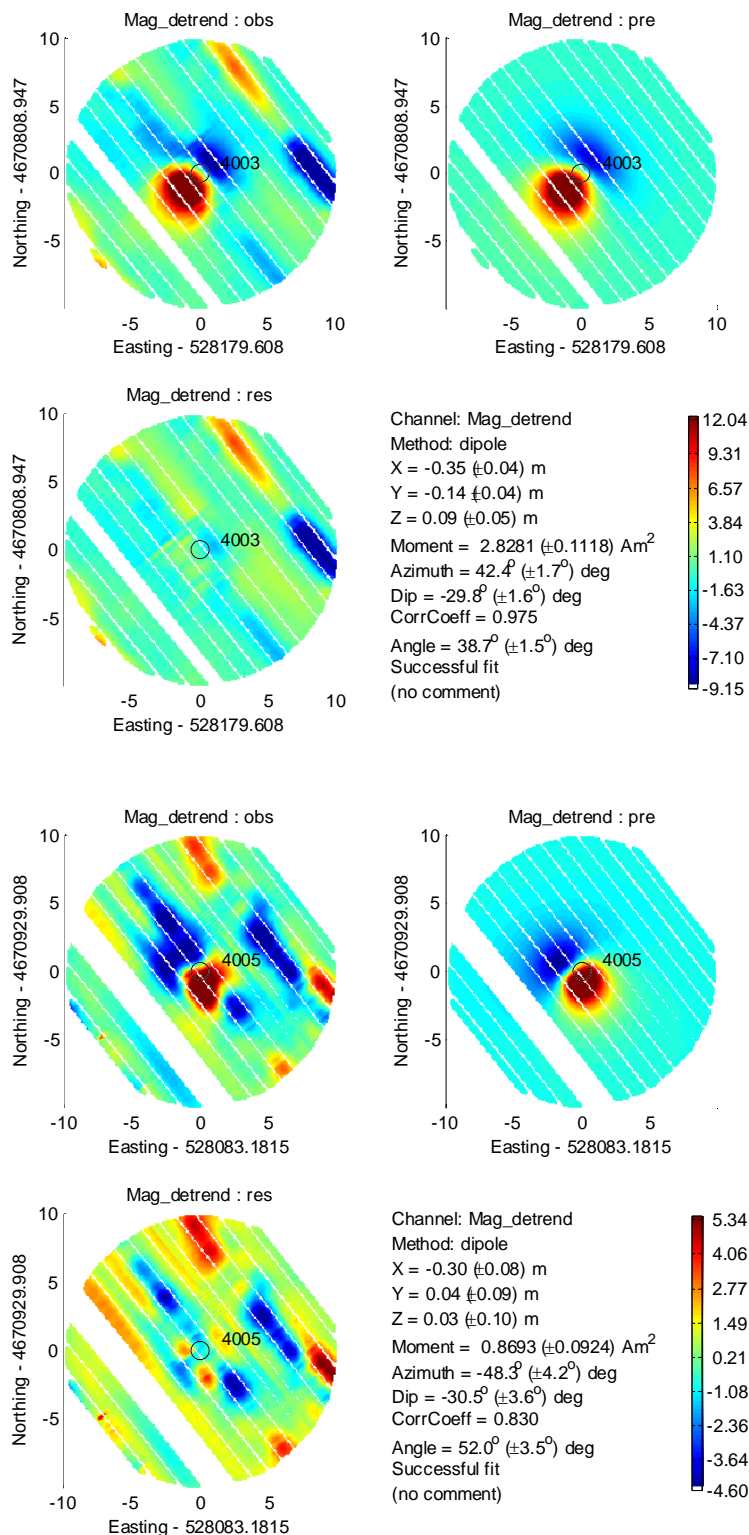


Figure 11. Dipole models of each of the 155 mm calibration items. The observed total-field data, modeled data, and residuals are shown along with the parameters of the dipole model.

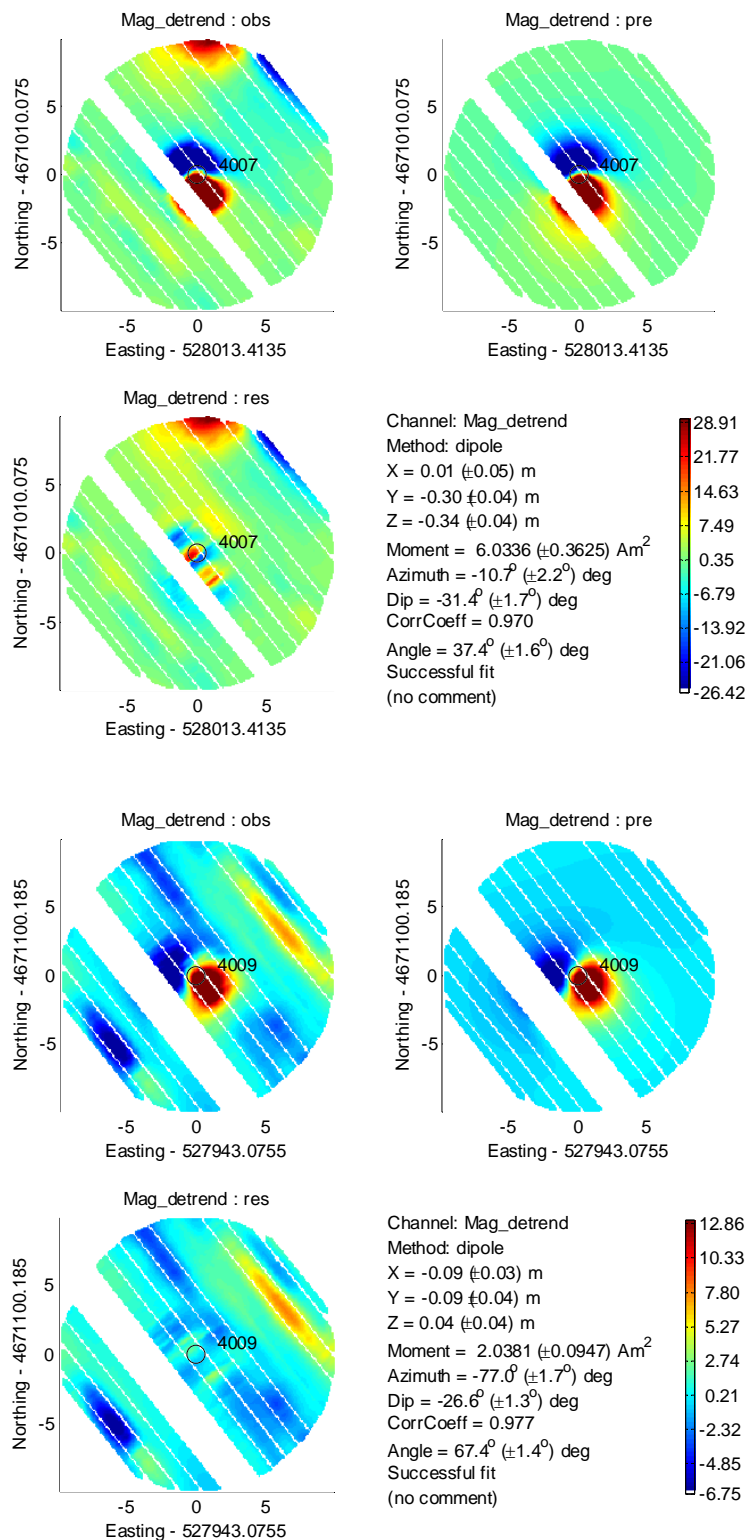


Figure 11 (continued). Dipole models of each of the 155 mm calibration items. The observed total-field data, modeled data, and residuals are shown along with the parameters of the dipole model.

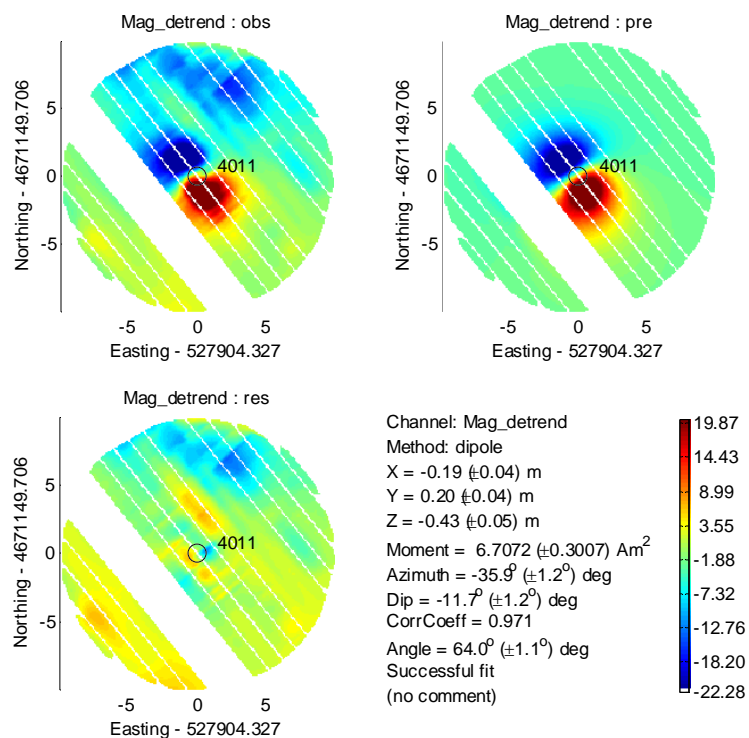


Figure 11 (continued). Dipole models of each of the 155 mm calibration items. The observed total-field data, modeled data, and residuals are shown along with the parameters of the dipole model.

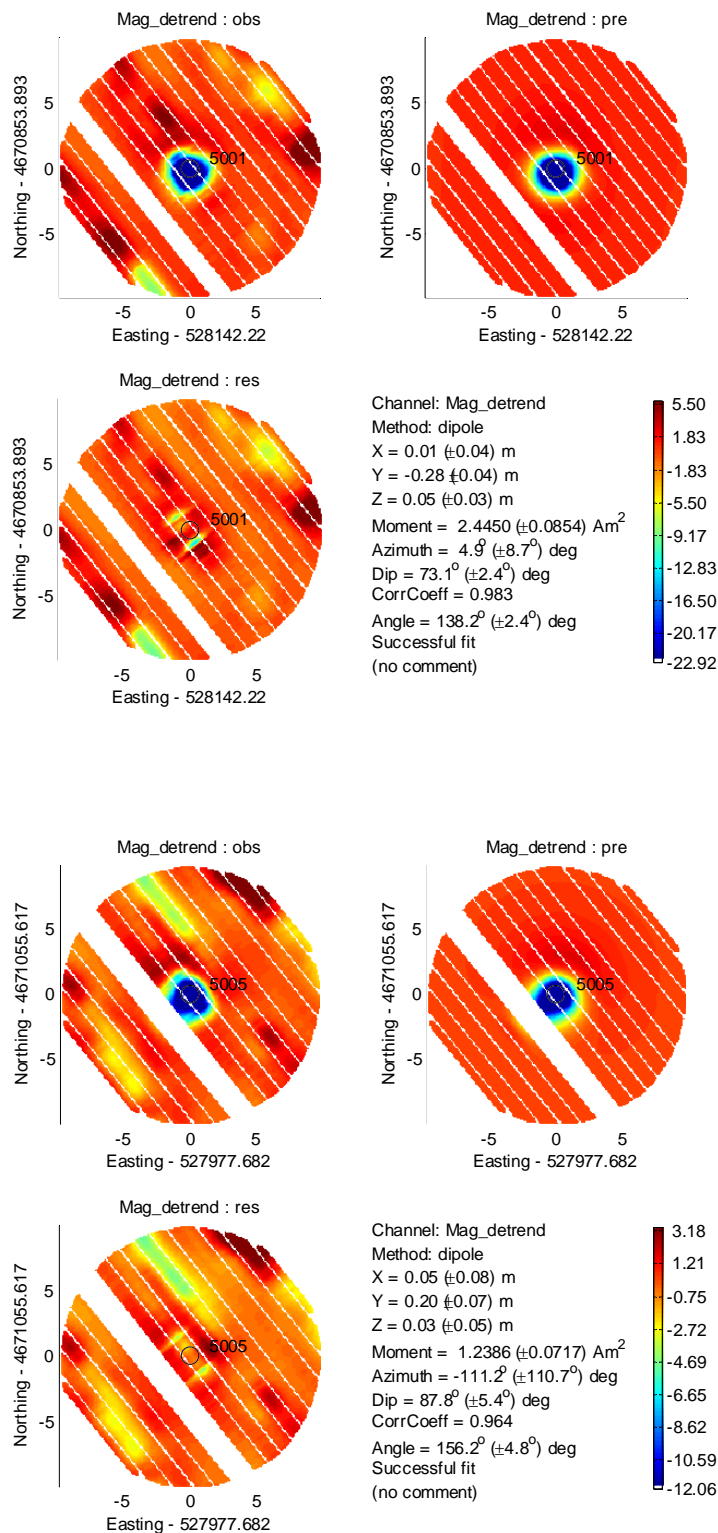


Figure 12. Dipole models of each of the two calibration loops. The observed total-field data, modeled data, and residuals are shown along with the parameters of the dipole model.

2.2.4 Summary of Test Flights and Suggested Improvements to System Prior to Deployment

The Ashland test flights demonstrated that:

- 1) Sensor noise level ranged from 0.1 nT in the outer sensors to 1.2 nT in the inner sensors;
- 2) The heading effect was on the order of 10s of nT for the outer sensors, with > 100 nT in the two inboard sensors;
- 3) That calibration items could be positioned to within 40 cm.

The following minor adjustments have been made to the system since the December 2006 test flights:

- 1) The ferrous steel bolts in the aircraft wheel have been replaced and the sensor spacing has been increased from 1.25 to 1.4 m. Prior to deployment we will fly a test-flight to determine if the noise levels and heading in sensors 3 and 4 are reduced to acceptable levels;
- 2) Increase the baud-rate and improve the serial interface on the SeaTerra DAS so that it can consistently support sample rates of 200 Hz. This adjustment has been made and will be fully tested during the pre-deployment test flights.

2.3 Factors Affecting Cost and Performance

For all airborne surveys, the largest single factor affecting the survey costs is the cost of operating the survey aircraft and sensors at the site. These equipment costs are related to capital value, maintenance overhead and direct operating costs of these expensive sensor and aircraft systems. Mobilization to and from the site increases costs as distance increases, and flexibility of scheduling is critical in determining whether mobilization and deployment costs can be shared across projects. In addition, low altitude surveys are limited by topography and vegetation and therefore these airborne technologies can be deployed only to sites with suitable conditions. One of the primary objectives of this demonstration is to compare the cost of deploying and using this system to the cost of deploying and using the HeliMag system. Because of the lower costs associated with the use of the aircraft and fuel, the MARS system is expected to demonstrate a much lower cost to operate than HeliMag. This cost will also be evaluated in comparison to the performance of the two systems.

Another significant cost factor in general for WAA and similar projects is data volume and the requirement for a robust data processing infrastructure to manage large amounts of digital remote sensing data. Efficient and secure management of these datasets requires a dedicated information technology infrastructure comparable to that of a mid-sized corporation or small government agency. However, for this demonstration, we will utilize the information technology (IT) and GIS infrastructure already created for the demonstration site through the WAA Pilot Program GIS demonstration (ESTCP 0537).

2.4 Advantages and Limitations of the Technologies

As with all characterization technologies, site specific advantages and disadvantages exist that dictate the level of success of their application. The general advantages of MARS technology include:

- The ability to characterize very large areas, and
- Lower cost as compared to ground-based and helicopter-based DGM methods.

There are advantages and disadvantages in using a fixed-wing platform. Open areas are very suitable for the fixed-wing systems. MARS can be flown quite flexibly, but obstacles such as trees, power-lines, etc., pose a safety hazard and have to be flown over, producing data gaps. In these conditions the helicopter platform will outperform MARS. The topography of a survey site plays a role as well. If the area is slightly hilly, MARS has no deployment limitations. However, mountainous areas and steep slopes are not suitable for fixed-wing systems. An advantage of MARS is the ability to fly more constant flight paths and straighter survey lines. Rapid positioning changes (change of direction and speed) do not occur frequently and therefore problems in positioning are generally avoided.

An additional advantage of the MARS system is the low-noise aspect of this platform. The CT SW aircraft is entirely made out of fiberglass composite materials; the only major metallic component is the engine. Since the rotation of the engine is very high-speed it only creates a high frequency noise to the data, which is above the frequency of the signal from items of interest in the ground. Most of the fixed metallic components of the system are replaced by non-magnetic components. The remaining metal parts are the engine and the rescue system of the plane, which are both fixed and create a constant signature depending on the movement of the plane in the magnetic field. This heading dependant signature can be removed with the use of a compensation system, recorded in real time along with the cesium vapor data and the positioning / altitude information in one data file. Careful attention has been given to the relative timing of the different sensors in the MARS system to avoid time delays or synchronization problems. Calibration loops flown in high altitude provide estimates of plane noise in correlation with the plane movement and orientation. Typical noise levels during operation are ~0.3 nT. This is the noise in the raw data, which fortunately has a very high frequency. A frequency domain filter is applied to produce data in the 0.1 nT range¹. Real time compensation along with calibration data from high altitudes are used to compensate the platform noise.

¹ We have yet to demonstrate 0.1 nT noise-floor on the in-board sensors and will conduct pre-deployment test flights to determine the expected noise-floor.

3. DEMONSTRATION DESIGN

3.1 Performance Objectives

Performance objectives are a critical component of this demonstration plan because they provide the basis for evaluating the performance and costs of the technology. For the MARS project, both primary and secondary performance objectives have been established. Table 5 lists the performance objectives for the MARS technology, along with criteria and metrics for evaluation, to be documented as a deliverable of this demonstration. Many of the performance objectives have been developed with the HeliMag system in mind and an important component of this demonstration is to compare the performance of the MARS to that system.

Note that with our planned 1.4 m sensor spacing and 5.0 meter transect spacing, there will be (on average) 60% overlap in data coverage (this is equivalent to the case for HeliMag data). This is to ensure that we minimize the chances of a gap in coverage during surveying. A survey gap will be defined as any area where the sensor separation is greater than 2 m or the survey height is greater than 4 m.

Table 5. Performance Objectives for the MARS Demonstration

Type of Performance Objective	Primary Performance Criteria	Expected Performance (Metric)	Actual Performance Objective Met? (future)
Primary/Qualitative	Ease of use and efficiency of operations for sensor system	Efficiency and relative ease of use	
Primary/Quantitative	Geo-reference position accuracy	Within 0.5 m (determined by ESTCP and daily calibration target dipole fit position estimates)	
	Target feature definition	Bias and standard deviation of daily calibration target dipole fit parameters within 25% of values for previous Kirtland HeliMag deployment	
Primary/Quantitative	Detection probability relative to the HeliMag	Pd (MARS) > 0.9 Pd (HeliMag) Pfa (MARS) < 0.5 (based on comparison with vehicular)	
Primary/Quantitative	Detection probability on emplaced objects	Pd (MARS) > 0.9 for items of 105 mm caliber and greater	
Primary/Quantitative	Detection of bombing target	Pd (Bombing Target) = 1 with Pfa < 0.67 (detection based on calculated anomaly density)	
Secondary/Quantitative	Terrain/ vegetation/infrastructure restrictions	Acres surveyed with MARS > 90% of planned survey area.	
Secondary/Quantitative	Operating parameters (altitude, speed, production level)	2-3 m above ground level (AGL); 68 knots (35 m/s); 400 acres/day	
Secondary/Quantitative	Ease of use: Navigational accuracy	95% of actual flight-path within 2 m of planned flight-path	
Secondary/Quantitative	Noise level (combined sensor/platform sources, post-filtering)	< 1 nT on all sensors determined by high altitude test flights	
Secondary/Quantitative	Data density/point spacing	< 0.175 m along-track < 2 m cross track	

3.2 Selecting the Test Sites

The WAA Pilot Program selected the Former KPBR as one of the demonstration sites. For that demonstration, two parcels totaling 5,000 acres on either side of Double Eagle Airport were chosen. Results from data analysis from the WAA Pilot Program confirmed the presence of three precision bombing targets (N2, N3 and NDIA), the SORT, and several additional areas of interest. The area to be surveyed using the MARS system will fall within the 5,000 acres surveyed by the HeliMag system; however, the potential for interference with Double Eagle Airport operations and the presence of high tension power lines and other infrastructure in portions of the area will limit the acreage at the Former KPBR that will be surveyed for this demonstration. Surveying within the WAA boundary where data have already been collected will provide the basis for directly comparing the results of the MARS and HeliMag technologies. Additionally, ESTCP will emplace test items within a designated area at the Former KPBR site. These items will be used as a blind test to validate the system's performance.

Additional acreage will be surveyed at the nearby Isleta Pueblo site. This area does not have airspace or infrastructure issues and will increase the range of geologic and topographic conditions to assess performance of the MARS system. Previously collected HeliMag and vehicular data will provide the necessary basis for comparison with the MARS system data.

3.3 Former KPBR Test Site History / Characteristics

The Former KPBR is a WWII-era former military training facility located about 10 miles west of Albuquerque, New Mexico. This FUDS consists of a total of ~38,000 acres, encompassing multiple target areas. It is located west of Albuquerque, NM and served as a training area for KAFB during WWII.

3.3.1 Munitions Use

Munitions known or suspected to have been used on the site include 100 pound (lb) practice bombs and 250 lb HE bombs. Target N2 is documented as a 160-acre quarter-section containing a circular night bombing target including power plant, underground cables, floodlights and target circle. Target N3 is documented as being within a 320-acre half-section near the northwest corner of the study area. This target was cleared in 1952, and large pits within the area have been hypothesized as open burn/open detonation (OB/OD) areas. The NDIA target area is a target circle. The SORT area was documented in the Archive Search Report (ASR) with location unknown, in the current conceptual site model (CSM) (Versar, 2005). The surveys conducted under the WAA Pilot Program confirmed its presence. These areas are shown on Figure 2.

Documented ordnance present on the site surface within the study area includes the following:

- M38A2 100 lb practice bombs and spotting charges
- M85 100 lb practice bombs and spotting charges
- 250 lb General Purpose HE bombs.

The primary aircraft in use at the Former KPBR was the AT-11 bomber trainer which carried up to ten 100 lb practice bombs. The B-18 bomber was also reportedly used, which could carry a 4,000 lb payload of bombs. Aircraft flares were also reportedly dropped. Information in the ASR indicates that a single 250 lb HE bomb was dropped “unofficially” by each trainee bombardier upon graduation from the training course, probably at the NDIA target area east of the N2 target area.

3.3.2 Demonstration Area Characteristics

The demonstration survey area is on a relatively flat terrace at about 6,000 feet mean sea level atop the Rio Puerco Escarpment which falls away to the west of the site. To the east of the study area, several volcanic cinder cones rise about 300 feet above the surrounding terrain. Gently rolling terrain on the study area generally varies by less than 50 feet in elevation, and is not incised by any significant drainage. Topographically, most of the site will be accessible to low airborne operations; significant constraints for operating the CT aircraft are posed by infrastructure such as high voltage power lines and airport operations.

The soils within the survey area are deep, well-drained homogeneous sandy loams formed on loess parent material with low magnetic mineral content. The vegetation is short-grass prairie and cultivated fields with very few trees and shrubs that would pose a constraint to low airborne operations.

Winter and early spring season weather (wind, rain, snow) may pose temporary scheduling constraints for low altitude operations on the site during the period of planned operations. Flights will be planned to begin shortly after sunrise to maximize operations during the least windy time of day. No surface hydrology factors are likely to exist on the site that would inhibit the MARS operations or provide a mechanism for MEC transport or burial.

3.3.3 Present Operations

The survey area is currently undeveloped. Land within the study area is primarily in City of Albuquerque ownership with small portions owned by the State. Existing uses include portions of the site that are within the Double Eagle Airport boundary and within a recreational shooting range in the western portion of the site. As shown on Figure 13, a 1,200-acre sewage treatment soils amendment processing facility is embedded in the central area of the study area and the airport is embedded in the eastern portion. Figure 13 also shows the configuration of utilities infrastructure crossing the study area, including several high voltage transmission lines, two high pressure natural gas transmission lines, water lines, an 8 inch gravity transmission sewage line, and a 6 inch natural gas pressure pipeline. Water wells, storage tanks, and transmission lines

serving the airport fall partly within the WAA study area. There is new construction in the southeastern portion of the area as well.

Coordination of low altitude airborne activities with activities at the Double Eagle Airport will be required. Double Eagle is not currently a tower-controlled airport (a tower has been constructed but is not yet operating), however operations immediately around the airport may require a Federal Aviation Administration (FAA) Notice to Airmen (NOTAM), coordination with FAA, and operational procedures on the common traffic advisory frequency (CTAF) and universal integrated communication (UNICOM) communications frequencies. We will coordinate with the airport manager to ensure that all required notifications are issued.

MARS activities near the shooting range will be restricted and must be scheduled in coordination with the City of Albuquerque Police Department. The shooting range is used by the police and sheriffs departments on Mondays and Tuesdays and open to the public during the remainder of the week. Because the shooting range cannot be closed during the periods of public use, the police and sheriff departments have agreed to accommodate the MARS survey during their scheduled range operations.

Overhead electric transmission lines pose constraints for MARS operations. Therefore, the estimated survey area assumes a 500 foot buffer around all transmission lines. During the demonstration, the on-site SKY manager and CT pilot will determine if 500 feet is a sufficient safety buffer based on current conditions. If not sufficient, they will determine whether a larger buffer is required or whether some areas will be excluded from the survey.

Portions of the site are planned for commercial or industrial development within the next decade and airport expansion into these lands is possible. Additional details about the Former KPBR site can be found in the CSM.



4/6/2007

3.4 Isleta Pueblo Test Site History / Characteristics

Isleta Pueblo is located in Bernalillo County, New Mexico, approximately 13 miles south of Albuquerque. It is the largest of the 19 pueblos situated within the Rio Grande Valley and was initially established in the 1300s. It is bordered on the north by the Sandia Military Reservation, which includes Kirtland Air Force Base (adjacent to Former KPBR), the Manzano Mountains on the east, and the Rio Puerco (a tributary to the Rio Grande) and Laguna Pueblo Reservation on the west. As well as the main pueblo, Isleta comprises the small communities of Oraibi and Chicale. The name “Isleta” is Spanish for “little island,” referring to the fact that when the Spaniards first arrived, the Pueblo was literally on an island of the Rio Grande. The Native American residents of the pueblo are from the Tiwa ethnic group.

3.4.1 Munitions Use

As mentioned in Section 1.3.2, approximately 7,000 acres of land were leased from the tribe in the 1950s for use as a target bombing range for aircraft from KAFB. Bureau of Indian Affairs files indicate that this area was used as a practice bombing range from 1956 to 1961 to determine the performance of fast aircraft during bombing runs. In the 1960s, visible ordnance debris was collected and piled for removal. Up to two tons of practice bombs and ordnance waste per acre were removed, but no explosive ordnance was found.

3.4.2 Demonstration Area Characteristics

The diverse terrain surrounding Isleta Pueblo ranges from the forested mountains of the Manzano Mountains, across the farm and grasslands of the Rio Grande river valley, to desert mesa. The demonstration site itself consists of open, semi-arid terrain. The area is relatively flat, open grassland with elevation varying from 5,100 feet above sea level on the west to a maximum of 5,400 feet and a broken escarpment on the east.

The weather in the Albuquerque area is generally dry and sunny all year, although temperature variations between winter and summer are significant. During the summer months, temperatures are well over 90° Fahrenheit most days, particularly during June and July, but there are usually no more than 15 to 20 days when the temperature reaches 100° F. By contrast, winters are cold and daytime temperatures can fall below freezing during December and January, although winter nights seldom drop to 0 ° F. The Sandia Mountains represent a broken segment of the almost continuous Rocky Mountain chain extending the length of the continent from north to south. They obstruct many of the storms that often impact northern New Mexico.

The soils in the Rio Grande valley floor are generally derived from alluvial deposits. The soil textures are characterized as sandy, loamy sand or sandy loam. These soils range from slightly to strongly saline and are moderately alkali-affected.

Vegetation is predominantly sparse, low-lying desert scrub.

3.4.3 Present Operations

Agriculture is the principal occupation of most of the Isleta residents. A high proportion of the population works outside the reservation. While Isleta Pueblo's current population numbers just over 3,000 people, it is a growing community with businesses primarily centered on tourism, gaming, and Native American arts and crafts. Major enterprises include the Isleta Casino and Resort, the Isleta Eagle Golf Course, and the Isleta Lakes Recreation Complex (campgrounds, fishing, picnicking).

3.5 Pre-Demonstration Testing and Analysis

Previous testing and analysis has been performed at the Former KPBR site under the existing ESTCP WAA Pilot Program. HeliMag (performed by SKY), LiDAR, and very large scale orthophotography (performed by other demonstrators) data were collected over the same area to be surveyed using the MARS technology. The results of the previous analyses confirmed the presence of target areas identified in the CSM, and several additional areas of concern were identified based on features and anomaly densities identified in the WAA analysis. Because both HeliMag and MARS technologies collect data using magnetic sensors, comparison of the two datasets will provide a cross-check of both technologies.

In 2003, the Naval Research Laboratory (NRL) conducted demonstrations of both vehicular and airborne magnetometer systems on approximately 1,500 acres at Target S1 within Isleta Pueblo. The objectives of this demonstration were to: demonstrate the NRL airborne system in a new geological environment against a new target set; measure the probability of detection and location accuracy of the airborne MTADS against the baseline set by the vehicular MTADS; and, to compare the NRL airborne MTADS with the airborne system developed by Oak Ridge National Laboratory, which surveyed the same 1,500 acres. The results of the MARS data collection will be compared against the NRL airborne MTADS results at Isleta Pueblo.

Some of the items detected during the 2003 survey at the Isleta site and the WAA demonstration survey at the Former KPBR were removed following the demonstrations. The locations of those excavated items will be provided by ESTCP following data collection and processing so they can be excluded from the comparison and scoring of the MARS system results.

3.6 Testing and Evaluation Plan

3.6.1 Demonstration Set-Up and Start-Up

Mobilization for this project will require:

- 1) Pre-mobilization equipment installation, testing, and test flights in Ashland, Oregon, prior to deployment to the site to verify that the system modifications described in Section 2.2.4 meet specifications and are operating as required.

- 2) Logistical coordination with the Albuquerque US Army Corps of Engineers (USACE) to schedule access to both the Kirtland and Isleta Pueblo sites as well as to determine any other required briefings, establish points of contact while on site, and address any other site specific issues;
- 3) Mobilization of the CT SW aircraft with sensor boom and positioning equipment, pilot, and operators; and
- 4) Deployment of ground support personnel to establish and operate GPS base stations, and provide logistical support. The entire data collection system will undergo standard pre-collection maintenance and calibration procedures.

A base of field operations will be established at the Double Eagle Airport to provide fuel and temporary hanger space during operations at the site.

3.6.2 Ground Control

RTK GPS provides centimeter-accuracy real time positioning and is used in the MARS system. It will also be used to generate positions for ground fiducials and for positioning ground calibration data and field verifications. The GPS base stations at both sites will be established on existing survey monuments (see Table 6).

Table 6. Locations of Survey Monuments at Kirtland in UTM, NAD-83

Name	Northing	Easting	Elevation
WAA-DE-1	3894549.388	331546.716	1838.933
WAA-DE-2	3891988.917	330487.583	1844.409
WAA-DE-3	3892488.676	336703.269	1771.262
ACS 2-F6	3889573.947	337337.344	1768.569
WAA-DE-5	3893029.178	333713.290	1793.518
NGS EAGLEAIR	3890596.422	337278.521	1767.998
NGS Q424	3882321.542	337925.050	1715.482

3.6.3 Sensor Calibration Targets

A calibration line will be established at the base of field operations at the Double Eagle Airport. To confirm its suitability for the calibration line placement, background noise data will be collected and reviewed before the calibration line is established. Should the background noise levels be too high, a different location (to be determined) for the calibration line will be identified. The calibration targets will be placed on the ground surface at a spacing of 50 m at the orientations as listed in Table 7. The locations of all calibration items will be surveyed to verify positional accuracy. Target positions will be surveyed at two altitudes and the resulting signatures compared to calculated responses to confirm that the system is operating at its expected sensitivity. Calibration line surveys will be conducted twice each day and the resulting signatures compared to calculated responses to confirm that the system operation. No targets will be buried and no attempt will be made to measure a probability of detection from the calibration data.

Table 7. Calibration Targets to be Emplaced

Item	Depth	Orientation
8 inch steel cube	Ground level	
100 lb bomb stimulant	Ground level	1 N-S; 1 E-W
155 mm projectile	Ground level	1 N-S; 1 E-W
2.7 inch warhead	Ground level	1 N-S; 1 E-W

Additionally, ESTCP will be emplacing items at a test area south of the airport. The locations and orientation of a selected number of items will be provided and used to calibrate the system in a manner similar to the calibration line described above.

3.6.4 Validation

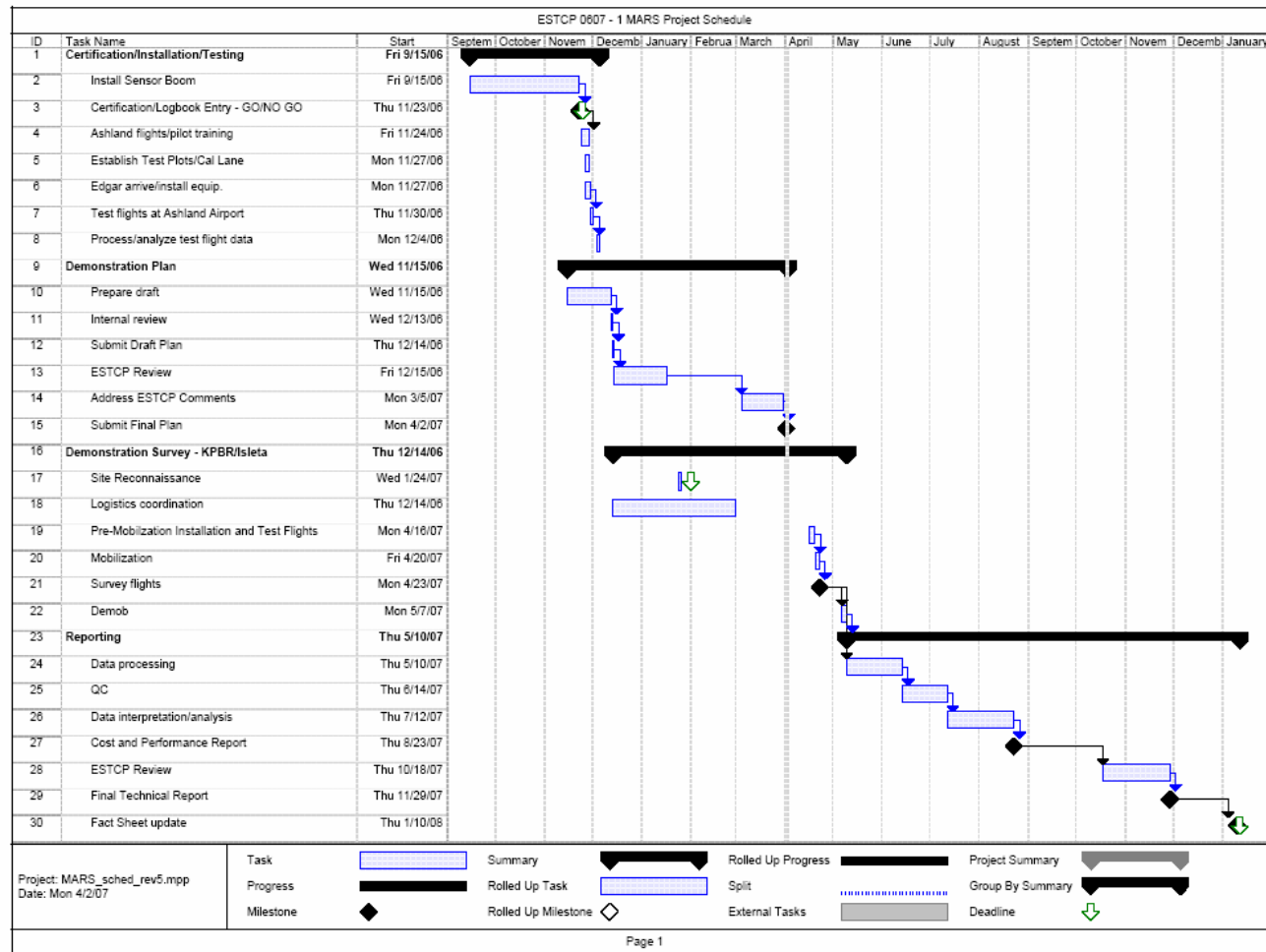
Because extensive ground survey data have been previously collected and analyzed at the Former KPBR as part of the WAA Pilot Program and the previous Isleta survey, no ground-based field-verification data will be collected from the two sites as part of this project. As noted, some of the items detected during the 2003 survey at the Isleta site and the WAA survey at Former KPBR were removed following the demonstrations. The locations of those excavated items will be provided by ESTCP so they can be excluded from the comparison and scoring of the MARS system results.

The ESTCP test plot also will be surveyed and emplaced items will provide a “blind” test of the MARS system’s detection capabilities.

3.6.5 Period of Operation

Table 8 is a GANTT chart showing the anticipated dates and duration of activities described in this demonstration plan.

Table 8. Planned Demonstration Schedule



3.6.6 Scope of Demonstration

The survey area at Former KPBR includes the three confirmed target areas and the SORT area as illustrated in Figure 14. This area coincides with the area previously surveyed using the HeliMag technology to provide a direct comparison of the magnetic data collected using the two different platforms. As noted, a portion of the 5,000 acres flown by the HeliMag system will be inaccessible because of infrastructure present at the site (high voltage power lines, etc.); however, data will be collected over as much of the area as can be safely flown. Based on a site reconnaissance conducted on January 25th and 26th, the estimated acreage that could be flown for the MARS demonstration is 3,400 acres. The area that is actually flown will be determined by the pilot and on-site SKY manager based on current site conditions. The flight safety decision process is described in the Health and Safety Plan (HASP) included as Appendix B.

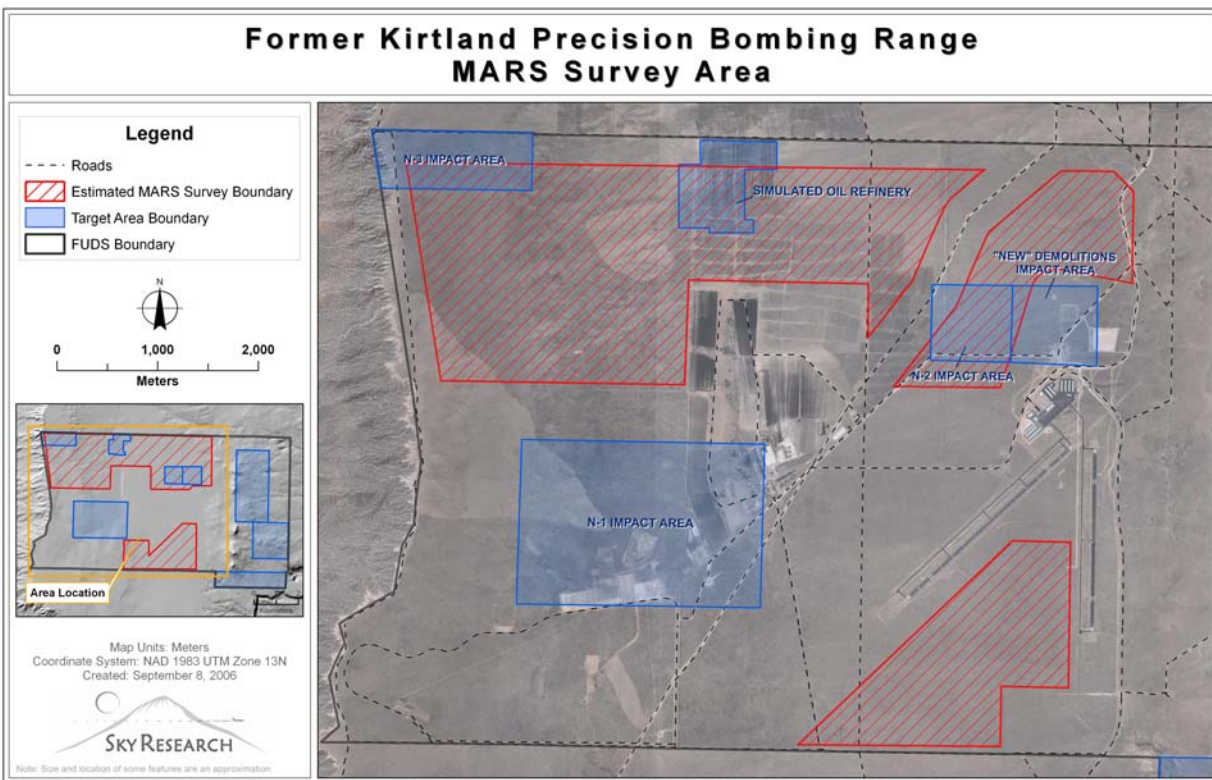


Figure 14. MARS survey area boundaries.

There are few physical or infrastructure restrictions to the MARS survey at Isleta Pueblo. The landscape is relatively flat, with sparse, low-lying vegetation. Although some training flights from KAFB are conducted in the area, they are at much higher altitudes than the MARS survey will be operating. We will coordinate with KAFB through the Albuquerque USACE regarding any required notifications or restrictions associated with the active installation's flight activities. The open terrain, sparse populace and lack of widespread land development at Isleta Pueblo presents fewer risks to operational safety than the Former KPBR site.

3.6.7 Operational Parameters for the Technology

Sky Research will deploy MARS system on the CT SW LSA, together with a pilot and a two- to three-person ground support team to operate the RTK GPS base stations, download data, refuel the aircraft, etc. The system uses an array of six full-field cesium vapor magnetometers deployed on a 7 m boom mounted under the aircraft wings. The aircraft is typically flown at a low altitude (2 - 5 m), with an average forward velocity of 35 m per second (m/s).

MARS System

- 6 Cesium vapor full-field magnetometers
- 1.4 m spacing on 7 m boom
- Along-track data density: 0.175 m at 200 Hz
- Magnetic compensation system
- Laser altimeter for height above ground
- Trimble MS750 dual-antenna GPS for positioning and yaw/roll information
- Digital compass for redundant attitude information

DAS

- AGS MK3 (SeaTerra proprietary DAS and frequency counter)

Ground Support

- RTK GPS Base Stations w/ radio link

Processing

- Custom Seaterra software for data merging and magnetic compensation
- UXOLab and Geosoft for initial surface interpolation and for target picking and classification
- Frequency domain notch filters to suppress 60 Hz noise and other harmonic noise sources (e.g., from the engine, propeller etc)

Flight Speed

- Average 68 knots (35 m/s)
- Range 55 to 80 knots (28 to 41 m/s)

Altitude

- 2 to 5 m AGL

Data density

- 1.4 m across track spacing
- Flight lines at 5.0 m separation to provide 60% overlap between adjacent passes
- Along track density 0.175 m (at 200 Hz sample rate)

Spatial Accuracy

- < 50 cm root mean square error (RMSE) in predicted target locations

Prior demonstrations and production experience with the HeliMag system have shown that flying lower and slower improves data quality and detection performance. The MARS system will be flying at nearly double the speed of the helicopter (35 m/s compared to 10 to 20 m/s) and will be at a comparable but likely slightly higher altitude (2 to 5 m depending on specific conditions). The CT SW will be flown at the lowest safe flying height to optimize data quality. In addition to this optimized deployment configuration we propose to re-fly parts of the Isleta Pueblo site and an approximately 400 acre section of the Former KPBR site at a higher speed and altitude (see Figure 15). The Former KPBR sub-area will be approximately 1,750 m North-South (the traverse direction) and 900 m East-West, and will cover the N3 impact area as well as the lower density areas to the North and South. The additional survey should take about a day to complete and will be flown at 4 to 5 m elevation at closer to 40 m/s (~80 knots). We will re-fly all of Isleta if we can fit in a high altitude test-flight during our mobilization. Otherwise, we will attempt to survey a sub-section of Isleta such that we cover 5,000 acres in total during the demonstration.

The intention with the higher altitude and speed surveys is to determine how detection performance degrades with increasing flight altitude. Essentially, we want to determine just what role MARS could play in WAA when flown higher and faster. While the magnetometer signal from a compact object is known to decay with the cube of distance away from the object, one cannot accurately predict detection performance at higher elevations. There are certain aspects of the system and background response, such as maneuver and background noise, that may vary as the altitude is increased. For instance, maneuver noise typically occurs on longer length scales than the signal from buried objects. As the flying height increases, the spatial footprint of anomalies increases and it may become more difficult to separate signal from maneuver effects.

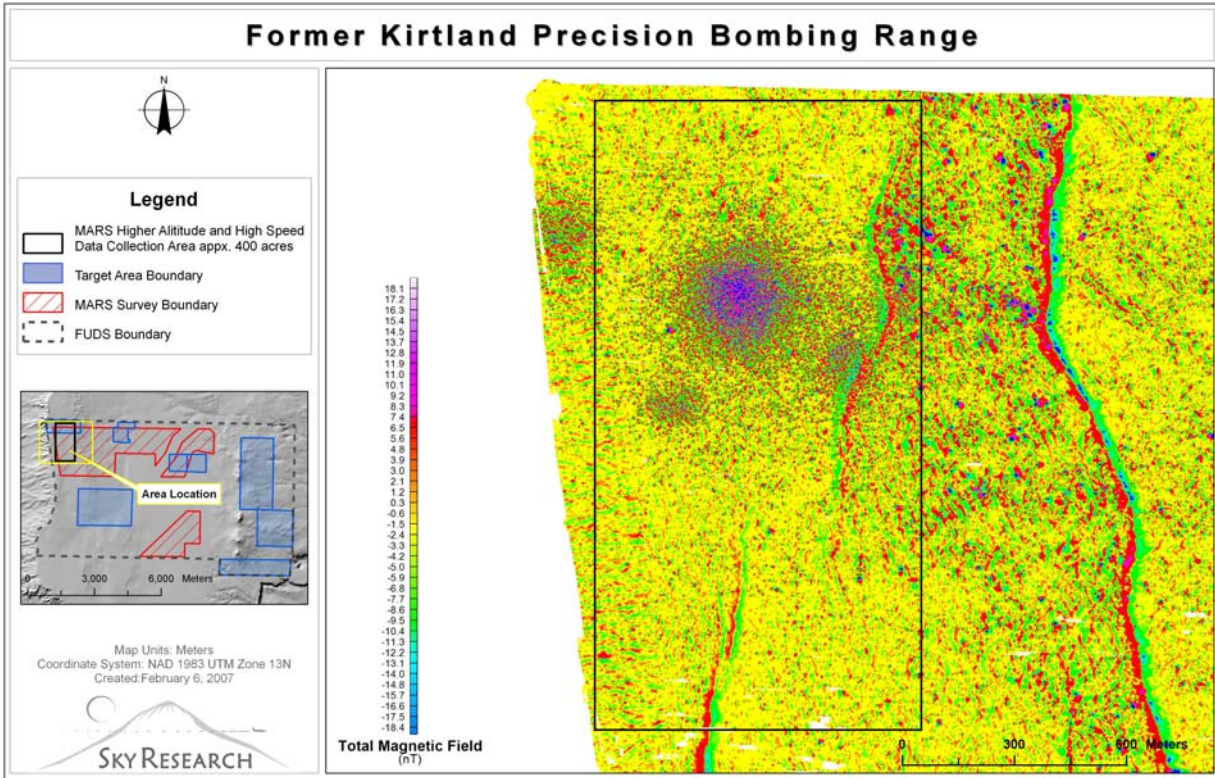


Figure 15. N3 Target area to be flown at higher speed and altitude.

3.7 Demobilization

At the conclusion of the surveys, all equipment will be removed from the site and sensor systems returned to their home base or on to a next deployment. No remediation of identified MEC will be implemented.

3.8 Health and Safety Plan

A HASP for the demonstration is included in Appendix B.

3.9 Management and Staffing

Figure 16 is a “wiring diagram” showing the project management and staffing structure, including the relationship between the Principal Investigator (PI), co-PI, project management personnel, technical and operations oversight, and technology lead personnel.

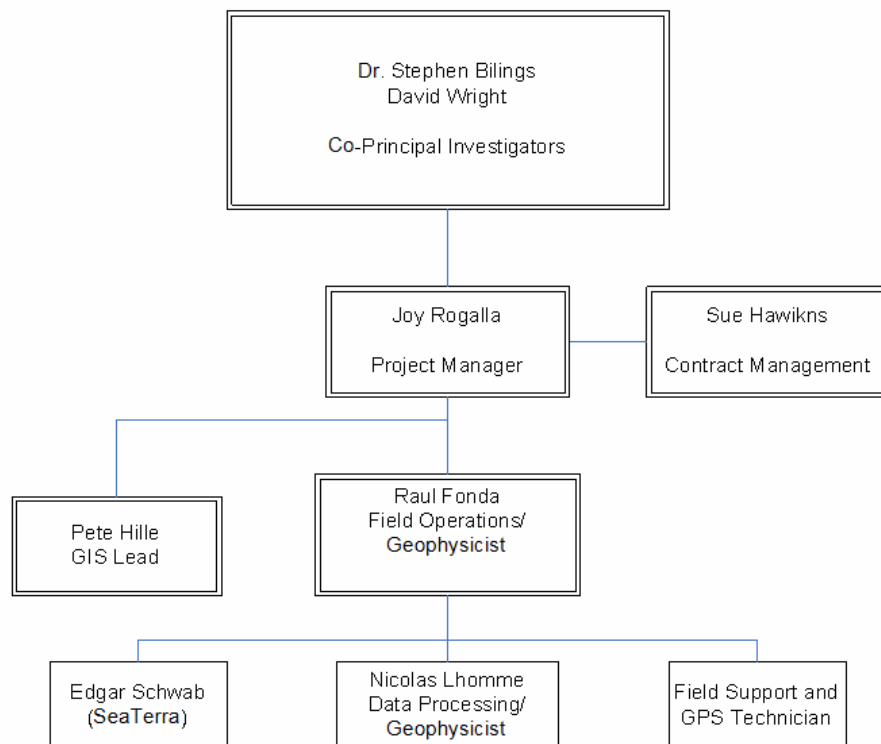


Figure 16. Project management and staffing for the MARS demonstration.

4. PERFORMANCE ASSESSMENT

4.1 Performance Criteria

The performance of the MARS technology will be measured against the criteria listed in Table 5. Table 9 provides more details on these performance criteria. All efforts undertaken for this demonstration will utilize careful and thorough documentation, objective data reporting and rigorously defined procedures and methods.

All performance metrics will be calculated for both the low and the high altitude flights. From the high altitude data it will not be possible to meet the performance specification that $P_d > 0.9$ P_d (HeliMag). The main performance criterion will be the probability of detecting a known bombing target.

4.2 Performance Confirmation Methods

Table 10 summarizes the performance confirmation methods that will be used. For performance confirmation of metrics related to probabilities of detection (P_d) and false alarm (P_{fa}) we anticipate using three types of validation information:

- 1) For the small subset of data where there will be overlapping MARS, vehicular and HeliMag data: we will use the vehicular data as ground truth and derive P_d and P_{fa} assuming the vehicular data are perfect ($P_d=1$, $P_{fa} = 0$): Note, since MARS is a WAA tool, we are not going to try to discriminate UXO from clutter so false alarms are defined as picks where there are no metal targets detected by the ground vehicular data. We will use the automatic wavelet detection algorithm on both the HeliMag and MARS – the threshold will be determined in the same manner as done for earlier HeliMag data at Pueblo. In this procedure we plot the number of targets versus threshold – this plot will have an inflection point where we start to pick into the noise (i.e., at lower thresholds the number of targets selected increases radically).
- 2) For regions with only MARS and HeliMag data we will conduct a similar analysis. Once the inflection point has been determined for both systems we will compare the following:
 - a. number of targets detected (to generate P_d);
 - b. relative target density results (to determine usefulness of MARS relative to HeliMag);
 - c. the threshold of the actual inflection point (to compare system performance);
- 3) For the ESTCP emplaced targets we will compute P_d for a range of ordnance types based upon the emplaced data.

Table 9. Performance Criteria

Performance Criteria	Description	Type of Performance Objective
Technology usage	Ease of use and efficiency of operations. Relative ease of use relates to the ability to fly the aircraft at the prescribed altitude, ability to incorporate the sensors and DAS system on the aircraft platform. Relative efficiency relates to the ability to consistently meet performance objectives.	Primary/ Qualitative
Target feature definition	Dipole fit feature estimates (parameters) derived from data collected twice daily over calibration targets. Parameters are X,Y,Z, size, dipole orientation	Primary/ Quantitative
Location accuracy	Predicted location of calibration items < 0.5 m from the calibration items (including daily and ESTCP calibration items)	Primary/ Quantitative
Bombing target detection (from high altitude data)	Pd (Bombing Target) = 1 with Pfa < 0.67 (detection based on calculated anomaly density). With this Pfa, we allow two false alarms per correct detection.	Primary/ Quantitative
Navigational accuracy	Actual flight path < 2 m from planned flight path. If the pilot is unable to fly lines within specification, gaps in coverage will occur. With a 7 meter swatch and a planned transect separation of 5 m, an appropriate specification is 2 m. At that tolerance, the left and right hand sensors on adjacent passes will overlap. If the adjacent pass is also 2 meters in error, then a data-gap will occur.	Secondary/ Quantitative
Anomaly detection/density distribution fidelity	Target detection probabilities/target density estimates relative to the HeliMag system	Primary/ Quantitative/ Qualitative

Performance Criteria	Description	Type of Performance Objective
MARS survey area coverage	Actual # acres surveyed as a percentage of planned # of survey acres: The percentage coverage will be determined by assuming that a gap in coverage is any area where the sensors are > 2 m apart or where the sensor height is > 4 m above ground-level.	Secondary/ Quantitative
Operating parameters (altitude, speed ,daily production rates)	Statistical assessment of operating parameter. Expect mean values to be 2-3 m AGL; 68 knots (35 m/s); 400 acres/day.	Secondary/ Quantitative
System noise	Accumulation of basal noise levels from all contributing sources other than environmental sources. These sources include: sensors and sensor platforms, mechanical motion noise, radio frequencies, etc. calculated by root mean square.	Secondary/ Quantitative
Data density/point spacing.	(# of sensor readings/sec)/ airspeed, and cross track data density; number of sensor survey lines/survey area width	Secondary/ Quantitative

Table 10. Expected Performance and the Confirmation Methods to Be Employed

Performance Metric	Confirmation Method	Expected Performance
Technology usage	Field experience using technology during demonstration for ease of use; ability to meet performance objectives for relative efficiency.	Relative ease of use and efficiency
Target feature definition	Statistical analysis of dipole fit parameters derived from data collected over the calibration line targets. These will be compared to HeliMag data collected over equivalent calibration items at the site during the WAA demonstration survey.	Bias and standard deviation of dipole fit parameters for each target are within 25% of HeliMag results
Probability of detection compared to HeliMag	Comparison with HeliMag data. Pd (MARS) will be compared to the Pd (HeliMag) and Pfa will be compared to vehicular data (see text).	Pd(MARS) > 0.90 Pd(HeliMag). Pfa < 0.5
Probability of detection on emplaced items	(# emplaced targets detected) / (total # emplaced targets)	Pd > 0.9 on 105 mm caliber and greater
Bombing target detection (from high altitude data)	Comparison to known locations of bombing targets. Detection will be declared based on elevated anomaly density (from automated picking algorithm).	Pd=1, with Pfa < 0.67
Navigational accuracy	Comparison of actual GPS track of each line against planned flight-path.	95% within 2 m
MARS survey area coverage relative to HeliMag	Calculation using GIS of the percentage of acreage surveyed relative to the planned coverage.	Coverage > 90% planned area.
System noise	Calculation of system noise using RMSE and based on data collected at high altitude (>500 ft AGL)	<1 nT on all sensors
Data density/point spacing	Statistical analysis of survey data using mean values from areas without large gaps (> 5 m in width).	0.175 m along-track 2 m cross track
Operating parameters (altitude, speed, daily production rate)	Computation of histograms and mean values of altitude and speed using GIS. Daily production rate will be calculated in GIS as acres/day, excluding entire day and partial day weather delays; partial day delays will be pro-rated for calculation of production rate.	2-3 m AGL; 68 knots (35 m/s); 400 acres/day

5. COST ASSESSMENT

5.1 Cost Reporting

Mobilization/demobilization, airborne surveys, processing, analysis, and reporting costs will be separately accounted and tabulated in the Cost and Performance Report. As noted, SeaTerra's data acquisition system and compensation system and SKY's magnetometers and GPS will be deployed for this demonstration survey, and the daily rental costs for that equipment will be reflected in the reported costs. Table 11 summarizes the cost tracking categories for the MARS technology.

Table 11. Cost Tracking

Cost Category	Sub Category	Details
Start-Up Costs	Mobilization	Includes planning, contracting, personnel mobilization, and transportation to site.
Capital Costs	N/A	
Operating Costs – Direct Environmental Activity Costs	Site Setup	Including establishment of survey control etc.
	Site Survey	Includes all survey costs to be reported as overall cost per acre. In addition, review daily logs to define cost/acre under different weather conditions and at different physical environments as applicable on the site.
	Data Processing	All actions required to produce a map of sensor data and select targets by threshold and QA/QC of data. Costs will be divided by data reduction and QC.
	Data Analysis	Includes analysis and statistical classification.
Indirect Environmental Activity Costs	N/A	
Demobilization Costs		Includes removal of equipment and personnel demobilization.
Other Costs	Project Management and Reporting	Interim and final reporting; and project management.

6. IMPLEMENTATION ISSUES

6.1 Regulatory and End-User Issues

As a WAA technology, the MARS system is subject to the same issues of regulatory acceptance of the methodology as investigated in the WAA Pilot Program. The ESTCP Program Office established a Wide Area Assessment Pilot Program Advisory Group to facilitate interactions with the regulatory community and potential end-users of this technology. Members of the Advisory Group include representatives of the US Environmental Protection Agency (EPA), State regulators, USACE officials, and representatives from the services. The Advisory Group has provided valuable feedback on the WAA methodology that is expected to facilitate its acceptance into the wider community. However, there will be a number of issues to be overcome to allow implementation of WAA technologies beyond the pilot program, including decision-making regarding areas with no indication of munitions use.

A main challenge of the Pilot Program is to collect sufficient data and perform sufficient evaluation that the applicability of these technologies to uncontaminated land and their limitations are well understood and documented. Similarly, demonstrating that WAA data can be used to provide information on target areas regarding boundaries, density and types of munitions to be used for prioritization, cost estimation and planning will require that the error and uncertainties in these parameters are well documented.

Therefore, a successful MARS technology demonstration will piggyback on the success of ESTCP WAA Pilot Program for regulatory acceptance of the overall WAA methodology. This technology will be one more tool in the WAA “toolbox” that provides flexibility for WAA technology selection that can reduce cost of characterization.

7. POINTS OF CONTACT

Table 12. Points of Contact

Point of Contact	Organization	Phone/Fax/email	Role in Project
Dr. Stephen Billings	Sky Research, Inc. Gerald McGavin Building, Suite 112A 2386 East Mall Vancouver, BC, V6T 1Z3 Canada	(Tel) 541.552.5185 (Cell) 604.506.9206	Co-Principal Investigator
Mr. David Wright	Sky Research, Inc. 9500 Kingsford Drive Cary, NC 27511	(Tel) 541.633.5255	Co-Principal Investigator
Ms. Joy Rogalla	Sky Research, Inc. 445 Dead Indian Road Ashland, OR 97520	(Tel) 541.552.5104 (Fax) 541.488.4606	Project Manager
Mr. Scott Millhouse	US Army Corps of Engineers Engineering and Support Center Huntsville Box 1600 Huntsville, AL 35807-4301	(Tel) 256.895.1607	Contracting Officer Technical Representative

Project Lead Signature:



APPENDIX A

ANALYTICAL METHODS SUPPORTING THE EXPERIMENTAL DESIGN

To be submitted at a later date if necessary.

APPENDIX B

HEALTH AND SAFETY PLAN

**Environmental Security Technology Certification Program
(ESTCP)**

**Sky Research, Inc.
Health and Safety Plan**

**Former Kirtland Precision Bombing Range
Minimum Altitude Remote Sensing**



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Acronyms

AGL	Above Ground Level
ATC	Air Traffic Control
CFIT	Controlled Flight Into Terrain
dbA	decibels on the A scale
ESTCP	Environmental Security and Technology Certification Program
ETA	Estimated time of arrival
FAA	Federal Aviation Administration
FUDS	Formerly Used Defense Site
HASP	Health and Safety Plan
KPBR	Kirtland Precision Bombing Range
MARS	Minimum Altitude Remote Sensing
MEC	Munitions and Explosives of Concern
OSHA	Occupational Safety and Health Organization
PPE	Personal Protective Equipment
RTKGPS	Real-Time Kinematic Global Positioning System
SAR	Search and Rescue
SKY	Sky Research, Inc.
USACE	US Army Corps of Engineers
UXO	Unexploded Ordnance
WAA	Wide Area Assessment

1. INTRODUCTION

This Health and Safety Plan (HASP) establishes site specific health and safety requirements in support of the Sky Research, Inc. (SKY) demonstration survey for the Minimum Altitude Remote Sensing (MARS) project. The survey will be conducted at the Former Kirtland Precision Bombing Range (KPBR), New Mexico, which is a formerly used defense site (FUDS), and a portion of the Isleta Pueblo that was used as a bombing target area in the 1950s and 1960s. Many of the general health and safety concerns are addressed in the overall project created by the Environmental Security Technology Certification Program (ESTCP) Office.

SKY will be performing low altitude airborne surveys to detect unexploded ordnance (UXO) and other munitions and explosives of concern (MEC) using the MARS technology, which comprises a magnetometer boom and positioning equipment mounted on a CT SW light sport aircraft. The planned survey activities are discussed in detail in the demonstration plan. This HASP addresses general aviation safety measures, guidelines for conducting survey operations, potential hazards associated with aircraft operations and ground support, and emergency response procedures related to this demonstration survey. As in all airborne operations, final decisions regarding safety of the aircraft and field crew are the responsibility of the on-site SKY manager and the pilot in command. In addition, compliance with the Federal Aviation Administration (FAA) regulations and standards for civilian aircraft operations, and FAA approved aircraft specific maintenance procedures and flight manuals are mandatory.

Because not every health and safety hazard encountered in the field can be anticipated, field personnel must be equipped and trained to recognize and respond to unforeseen hazards. Above all, employees must maintain a high level of safety awareness and exercise common sense and good judgment when confronted with a hazardous or unsafe situation.

All personnel and visitors involved with SKY activities at the site are expected to read and abide by all provisions of this HASP. All personnel participating during on-site activities will sign a document stating that they have read, understand, and will abide with the requirements of the HASP. This HASP provides guidelines to protect personnel, the public, property, and the environment from hazards associated with site activities and potential site contaminants.

2. AIRCRAFT OPERATIONS

2.1. General Operational Guidelines

The following are general guidelines for performing airborne survey operations.

2.1.1. Aircraft Ground Support Operations

- Daily inspections and preflight inspections of aircraft and equipment installations will be performed pursuant to manufacturer's specifications.
- Flight plans are to be filed as appropriate. Where flight plans are required by local authorities, a company flight plan will be made and monitored.
- Preflight briefings are to be performed prior to each survey flight. Ground crews must be aware of planned flight activities, fuel reserves, and estimated return times.
- Weight and balance calculations must be performed after any modification to the aircraft, including initial installation of any survey equipment.
- Daily weather forecasts are to be obtained prior to commencement of survey operations.
- Site specific hazards will be addressed prior to commencement of survey operations.
- Ground support personnel will wear proper Personal Protective Equipment (PPE).
- During landing and takeoff, ground personnel will remain well clear of the aircraft.
- Never approach or leave the aircraft without the pilot's knowledge – always approach and leave the aircraft within sight of the pilot.
- Fueling is to be performed by qualified personnel only. Non-qualified personnel must stay clear of the aircraft during fueling operations.
- The aircraft must be grounded prior to fueling operations.
- All survey equipment is to be turned off during fueling operations.
- Fueling personnel will have absorbent materials available for spill cleanup.

2.1.2. Airborne Operations

- The pilot in command has complete jurisdiction over all aircraft related operations, emergency response activities and requirements.
- **No aircrew member will fly while under the influence of substances, including alcohol and illegal, prescription, or over the counter drugs, which may impair physical or mental acuity.**
- The aircraft operator shall maintain up to date insurance.
- Only necessary personnel are permitted on board during flight operations.
- The pilot in command has the authority to abort any flight for safety considerations.

- The pilot in command may deviate from survey specifications (speed, altitude and/or flight duration) for safety considerations.
- Over-flight of restricted areas may only be performed with authorization from the appropriate authorities.
- The pilot is in 2-way radio communication with ground personnel (if necessary or required).

2.2. Low Altitude Airborne Surveys

2.2.1. MARS – CT SW Light Sport Aircraft

Sky Research will deploy the MARS system on a CT SW platform (Figure 1). The field crew includes the pilot and a two-person ground support team to operate the data collection system and the real-time kinematic global positioning system (RTK GPS) base stations. The MARS system uses an array of six full-field cesium vapor magnetometers deployed on a boom mounted to the wings and fuselage of the aircraft. The CT SW is typically flown at a low altitude (2-3 meters above ground level [AGL]), with a forward velocity of 35 meters per second. The sensor boom is lightweight and does not extend beyond the wings.



Figure 1. SKY CT SW.

2.2.2. MARS Operational Guidelines

Site reconnaissance will be conducted in advance or upon arrival at the site by an authorized SKY pilot to assess the accessibility of the survey areas. A flight risk analysis will be conducted based on the topography, infrastructure and other site features to identify areas that are safe to fly. Areas determined unsafe for any reason will not be included in the survey. Table 1 presents a hazard assessment matrix. Site conditions with low severity and probability of occurrence will not be considered to pose a threat to the pilot or operator, and those areas will be surveyed. Site conditions with medium hazard severity and improbable probability of occurrence will be considered acceptable. If conditions at any portion of the site are determined to fall in any other medium or high hazard severity and probability of occurrence, those areas will not be surveyed.

Table 1. Hazards Matrix

HAZARD SEVERITY		HAZARD PROBABILITY				
		FREQUENT Likely to Occur Frequently During The Test	PROBABLE Will Occur Several Times During the Test	OCCASIONAL Likely to Occur Sometime During the Test	REMOTE Unlikely but Possible to Occur During the Test	IMPROBABLE So Unlikely It Is Assumed Occurrence May Not Be Experienced
		A	B	C	D	E
CATASTROPHIC Death or System Loss	I	High	High	High	High	Medium
CRITICAL Severe Injury or Major System Damage	I I	High	High	High	Medium	Low
MARGINAL Minor Injury or Minor System Damage	I I I	High	Medium	Medium	Low	Low
NEGLIGIBLE Less Than Minor Injury or System Damage	I V	Medium	Medium	Low	Low	Low

MARS surveys will be performed at 2-3 m AGL. Due to the low altitude flying during data acquisition, there are additional operational guidelines that must be followed.

- Pilots must have a minimum of 2,000 total flight hours including training on the CT SW with the magnetometer boom installed.
- A single pilot shall be restricted to 6 hours of flight time and 14 hours of duty time for data collection flights (the reduction in flight time versus the FAA restriction of 8 hrs reflects the higher concentration levels required for low level surveys).
- If possible, two pilots will be used in an alternating flight format so that aircraft utilization may be maximized without compromising pilot rest periods or daily flight hour restrictions.
- During each flight the pilot will take a five-minute 'high altitude' break every hour, or more frequently if judged necessary by the pilot.
- Each pilot will be allowed adequate time to become comfortable with the aircraft flight characteristics and navigation system prior to attempting very low level survey flying.

The nature of the survey also requires stricter limits on environmental conditions. Survey flights will be terminated when:

- Cross winds exceeding 20 knots or conditions as deemed by the pilot are too unpredictable to continue low level surveys;
- Visibility is less than 2 miles; and
- Precipitation obscures the pilot's view (even light precipitation will have a deleterious effect on visibility because the wind screen is not blown clear at low airspeeds).

2.3. Airborne Survey Specific Hazards

Mechanical Failure

Description: Mechanical malfunction is a common cause of aircraft accidents. The nature of the modification to the airframe required for this project increases the level of risk.

Mitigation: It is the aircraft operator's responsibility to ensure that all scheduled inspections and maintenance activities are performed in accordance to FAA and aircraft manufacture's regulations.

Additional inspections of the survey modification FAA STC SR01367NY are required upon installation and periodically thereafter in accordance with document entitled "Instructions for Continued Airworthiness."

Injury due to Contact with Propeller

Description: During startup of the aircraft, the propeller presents a risk to personnel working near the aircraft. The propeller is almost invisible while it is spinning, and contact can be fatal.

Mitigation: In light of this risk, the following rules must be obeyed while the engine is operating:

- Only personnel essential to the survey operation may approach the aircraft.
- Never approach the front of the aircraft.
- Never approach or leave the aircraft without the pilot's knowledge – always approach and leave the aircraft within sight of the pilot.
- Never throw anything to or from the aircraft.
- Loose clothing, specifically hats or scarves, must not be worn near the aircraft.
- If long items (survey poles, etc.) must be handled near the aircraft, they must be kept well away from the propeller.

Controlled Flight into Terrain (CFIT)

Description: The term 'controlled flight into terrain' is used to describe accidents where mechanical failure did not cause the aircraft to hit the ground. Low-level, UXO style, survey operations bear an increased risk of CFIT due to:

- The extremely low altitudes required for this type of survey;

- The physical addition of the boom structure which could present a hazard when flying near obstacles (e.g. fences, trees, and hills) as well as during banked turns; and
- The changes in aircraft flight characteristics due to the presence of the aforementioned boom.

Mitigation: Clearly one of the dominating factors in reducing the risk of CFIT lies with the skill level as well as mental and physical state of the pilot. The MARS operational guidelines described in Section 2.3.2 will be followed to minimize the risks inherent to this kind of work.

The nature of the survey also requires stricter limits on environmental conditions. Survey flights will be terminated when:

- Cross winds exceed 20 knots or as deemed by the pilot to be too unpredictable to continue low level surveys;
- Visibility is less than 2 miles; or
- Precipitation obscures the pilots view (even light precipitation will have a deleterious effect on visibility because the wind screen is not blown clear at low airspeeds).

2.4. Emergency Response Procedures (Airborne Operations)

These site specific emergency response procedures are intended to provide a preplanned course of action to cover aircraft related emergencies during survey operations. A list of contact numbers and pertinent information will be maintained at the base of operations. All actions will be initiated by the project manager on site. Conditions resulting in the invocation of these procedures are defined as Alert Levels I, II, or III. Definitions of each Alert Level and appropriate responses are provided as follows:

Level I - Overdue Aircraft:

Initiated by:

- A missed scheduled radio report or estimated time of arrival (ETA) by ten minutes.

Objective:

- To ascertain if delays in reporting or arrival are due to communication difficulties, or diversion of aircraft due to weather or in-flight problems.

Action:

- Request a communication search from local air traffic control (ATC) authorities.
- Prepare for a ground search (where feasible).
- Take appropriate action, including progression to Alert Level II.
- Begin log of actions and timelines.

Level II – Missing Aircraft

Initiated by:

- Missed scheduled radio report by 30 minutes.
- Missed ETA by 20 minutes.
- Receipt of radio report of problems in flight.
- Failure to return after fuel supply including reserves is exhausted.

Objective:

- Ascertain if the aircraft has landed at an alternate location.

Action:

- Advise ATC and request action plan to be initiated.
- Call local Search and Rescue (SAR) or emergency response teams and advise of overdue aircraft.
- Perform ground search of alternate landing sites.
- Take appropriate action, including progression to Alert Level III.
- Update log of actions and timelines.

Level III – Missing Aircraft Presumed to have Crashed

Initiated by:

- Receipt of a MAYDAY, SOS, or ELT signal from the aircraft, or ground.
- Report of a distressed or downed aircraft.
- Missed ETA by 30 minutes and failure to make radio or visual contact at alternate landing sites.

Objective:

- Locate downed aircraft as quickly as possible, ascertain medical requirements, and dispatch immediate medical help.

Action:

- Provide location information (including last known position, and planned flight activities) as well as all pertinent flight plan information (helicopter type, registration, number of passengers) to SAR personnel.
- When aircraft is located, note time, specific location, condition of crew and conditions around crash site including nearest landing zone and ground access routes.
- Advise and update appropriate emergency personnel (local police, ambulance, fire department, ATC). Transfer command to trained SAR personnel (civil or military) at earliest possible time without compromising the above-mentioned objectives.
- Continue detailed log of actions and timelines.

3. GROUND SUPPORT OPERATIONS

3.1. Ground Support Field Tasks

Ground support field operations are detailed in the demonstration plans and are summarized as follows:

- Pre-flight site visits
- Field oversight activities, including coordinating and managing site preparation operations
- GPS base station operation
- Field calibrations (record basic site information, photos, RTK-GPS coordinates, feature measurements)
- Provide first aid kits and fire extinguishers for use at the office trailer and field work sites and vehicles
- Provide basic first aid to injuries until emergency response personnel arrive

The sections below evaluate information on UXO hazards likely to be encountered, as well as physical and biological hazards at the site. The potential of these hazards to affect the field activities is also discussed.

3.1.1. Unexploded Ordnance

Many of the survey areas have not been surface cleared of UXO. UXO avoidance procedures will be followed at all times on site while providing ground support.

3.1.2. Motor Vehicles

All SKY personnel operating company owned, leased or rented motor vehicles on site will hold a valid drivers license and comply with local, state and federal traffic regulations. Personnel will perform safety inspections to verify vehicle operability daily. All personnel will drive defensively and wear seat belts while vehicles are in motion. A Class C driver's license is required for personnel driving the fuel truck.

3.1.3. Physical Hazards

Personnel may be exposed to physical hazards, such as severe heat stress; excessive noise levels; and slip, trip, and fall hazards. Engineering controls will be used whenever possible to control physical hazards. Personnel will also use appropriate PPE to minimize exposure to these hazards.

In the event of severe weather, site activities will cease until the field team leader has determined that it is safe to resume operations. Severe weather will include any type of climatic anomaly that presents additional, uncontrollable risk to personnel health and safety.

To prevent heat or cold stress problems, the field team leader will closely monitor personnel working in extremely hot, wet, or cold weather. If conditions become extreme, personnel will be required to take rest and fluid breaks to reduce the likelihood of heat or cold stress.

Excessive noise levels may be generated from field equipment, aircraft, and other heavy equipment. The field team leader will qualitatively monitor noise levels and will require site personnel to wear hearing protection whenever noise levels are perceived to be dangerous.

Noise control measures will include the following:

- Providing protection against noise exposure for all site personnel when necessary. Action levels will be based on the United States Army Corps of Engineers (USACE) Safety and Health Requirements Manual (EM 385-1-1), Section 23, Noise Control, and regulatory requirements established by OSHA.
- Using feasible engineering or administrative controls, whenever noise levels exceed specified limits. According to OSHA regulations, the action level for 8-hour exposures is 85 decibels on the A scale (dBA), measured using the slow response mode. According to the USACE Safety and Health Requirements Manual, permissible noise exposure for 8 hours is 90 dBA. For this project, the 85-dBA limit will be used.

Other physical hazards associated with the site may include the following:

- Uneven terrain and heavily vegetated areas
- Sun exposure
- Hunters
- Vehicle traffic
- Cattle, antelope, horses, coyotes and small mammals

3.1.4. Biological Hazards

Biological hazards include animal bites or stings that may cause localized swelling, itching, and minor pain and can be handled by basic first aid treatment. The bites of certain snakes, lizards, and spiders may contain sufficient poison to warrant medical attention. In addition, ticks can spread Rocky Mountain spotted fever and Lyme disease; dogs, skunks, foxes, and other small mammals can spread rabies; and mosquitoes can spread West Nile and encephalitis viruses. Venomous snakes are indigenous to these sites. Cactus spines are an additional hazard in desert areas. Field staff should be aware of their surroundings and avoid contact with all types of cacti to minimize the potential for irritation or injury from this hazard.

Bee and wasp stings, spider bites, and other insect bites may cause allergic reactions. Anaphylactic shock from stings can lead to severe reactions in the circulatory, respiratory, and central nervous systems of an allergic person and can cause death in severe cases. Personnel assigned to this project who are allergic to insects will be required to carry their prescribed treatment and will notify the field team leader of the nature of any allergies or health problems, as well as the location of medications. All stings or bites will be taken seriously. Personnel stung

or bitten will be required to stop work and will be observed for signs of severe swelling, shortness of breath, nausea, or shock. Medical attention will be obtained immediately if any of these symptoms appear. To prevent exposure to insect bites, site personnel will use insect repellents as appropriate. A first aid kit available on site will contain the necessary supplies to treat bites, stings, and other minor injuries. All on-site personnel will be knowledgeable in standard first aid procedures.

4. SITE CONTROL

Tasks associated with the site activities involve work in areas where hazardous substances or UXO could be present. However, if unexpected hazards are encountered in work areas, the field team leader will contact the appropriate authorities. If appropriate, barrier tape or traffic cones will designate the hazard zone. Access to a contaminated exclusion zone will be restricted to authorized personnel.

The field team leader will identify routes and areas that personnel are authorized to enter. The following sections discuss site access communications, the buddy system, safe work practices, and HASP enforcement as site control measures.

4.1. Site Access

Because areas to be visited during this project are not active military installations, Sky Research personnel will control site access while the survey is being conducted. Persons granted access to the sites will be required to follow HASP entry and exit procedures. Non-field team visitors to the sites are required to sign a visitors log and be safety briefed before going on site.

4.2. Communications

Successful communication between field teams and among field personnel is essential. The following communication systems, when appropriate, will be used during field activities:

- Cellular telephones
- Hand signals
- Field Radios

Field Radios or Cellular telephones will be used to communicate with parties outside of voice contact range and for emergency situations.

Hand signals may be used to supplement voice communication. The following standard hand signals will be used in case of radio communications failure or for emergency onsite communication:

- | | |
|--------------------------------|------------------------------------|
| • Both hands on waist | Return to support zone immediately |
| • Hands on top of head | Need assistance |
| • Thumbs down | Negative; no |
| • Thumbs up | Positive; yes; I'm all right |
| • Fist raised above head-level | Stop |

A list of emergency and installation telephone numbers for each site is provided in Table 1 (see Section 8.1.5). This list will be kept, with a map of the medical evacuation route(s), in all vehicles during site activities.

4.3. Buddy System

Personnel will use the buddy system during all onsite activities. The buddy system requires that two people work as a team, each looking out for the other. Buddies must maintain continuous line-of-sight contact with one another and be in a position to physically assist each other if assistance is necessary. Personnel will not be allowed to enter the site alone; a buddy must accompany each person. In emergency situations, personnel will evacuate the site using predetermined egress routes.

4.4. Safe Work Practices

Experience indicates that individuals working at UXO-contaminated sites are tempted to collect UXO items as souvenirs while on site. **Souvenir hunting while on the site is expressly prohibited.**

Anyone observed picking foreign objects off the ground will be immediately expelled from the site. Even ordnance that is marked as inert may contain explosive charges in the fuses, unburned propellant, or other hazards.

Other general safe work practices for site operations include the following:

- All site operations will be discontinued immediately if an unforeseen hazardous condition develops
- Only personnel and equipment needed to perform the required tasks will be permitted on the site
- Matches, lighters, and other spark- or flame-producing devices are prohibited on the sites
- Site operations will cease immediately upon the approach of an electrical storm or other severe weather conditions
- If a fire occurs that may involve explosive materials, all personnel will immediately evacuate to the previously designated safe area using predetermined routes
- Consumption of alcoholic beverages onsite is prohibited. Personnel having consumed alcoholic beverages during lunch or other breaks will not be allowed onsite
- Effects of extreme climate conditions should be closely monitored during hot periods and all personnel should be aware of the symptoms and effects of heat stress, heat exhaustion, and heat stroke

Workers will be aware of any potential trip and fall hazards. Whenever possible, trip and fall hazards will be eliminated or clearly identified with yellow caution tape. Site activities will proceed with caution in any area where the presence of utility lines (such as gas, telephone, and other lines) is known or suspected.

5. EMERGENCY CONTINGENCY PLANNING

The field team leader and site manager will be notified of any onsite emergencies, and will be responsible for ensuring that appropriate emergency procedures are followed. A list of emergency telephone numbers and directions to the nearest hospital will be available onsite. Hospital route maps will be kept in all site vehicles. These emergency procedures will be coordinated with the Albuquerque USACE and/or Isleta Pueblo Environment Department staff before site work begins. PPE, emergency chain of command, evacuation procedures, emergency equipment, and emergency procedures are described in the following sections.

5.1. Personal Protective Equipment

Site personnel will wear long pants and ankle-high boots. Safety glasses and gloves will be worn when handling fuel or other potentially hazardous materials. If heavy machinery is in use, hard hats must be worn. If hardhats are to be worn in UXO areas, then they will be firmly attached to the head of the wearer.

Other PPE at the site will be discussed during the introductory safety, health, and emergency response briefing. The field team leader will also discuss site- and weather-specific PPE for the site activities as needed.

If unexpected hazardous substances or respiratory hazards are encountered, operations will cease.

5.2. Emergency Chain of Command

A clear chain of command in emergency situations will ensure clear and consistent communications among site personnel and will result in a more effective emergency response. The field team leader will direct SKY emergency response operations and designate duties to other site personnel. The field team leader will make initial contact with off-site emergency response teams (such as first aid, fire, or police); stop work if necessary; and provide for on-site first aid and rescue.

5.3. Evacuation Procedures

If required, personnel will evacuate work sites along routes designated before the field activities begin. In most cases, this will be the most direct route to a designated safe area such as a road or site trailer. During evacuation, equipment will be placed so as not to impede emergency escape and evacuation along cleared paths.

5.4. Emergency Equipment

At a minimum, the following emergency equipment will be present in each vehicle and on site:

- First aid kit
- Multipurpose fire extinguisher
- Cellular telephone
- Field Radio

5.5. Emergency Procedures

Procedures for specific types of emergencies are outlined in the following sections; these emergencies include explosion and fires, chemical spills, and injuries or medical emergencies.

5.5.1. Explosion and Fires

In the event of an unplanned explosion or fire, personnel in the area of the explosion or fire should check to ensure that no personnel were injured. In the case of such an event, personnel should evacuate the site along designated access paths. Personnel evacuating the site should notify the site manager using cell phones or radio as soon as practical, preferably while evacuating the site.

If personnel are injured, other personnel in the area should assess the situation and notify the site manager by cell phone or radio. If imminent danger does not appear to be a risk, all personnel should stay with injured parties and render first aid support. Otherwise, the injured party should be evacuated from the area along the designated access paths, unless moving the injured party would complicate the injury drastically. SKY personnel will notify the appropriate volunteer fire department or emergency response team.

If personnel are injured, the onsite personnel will escort the volunteer fire department or emergency response team across the site using the shortest linear distance to the injured party from the access road. While the volunteer fire department or emergency response team is assisting the injured party, other personnel will be escorted off the site.

The field team leader will witness the evacuation procedures and conduct a head count of all personnel. The team leader will then notify the volunteer fire department and emergency response team and will act as the onsite incident commander until the volunteer fire department or emergency response team arrives to assume incident command duties. When the volunteer fire department or emergency response team arrives on site, onsite personnel will advise the responding crew chief of the location, nature, and identification of the explosion or fire.

Site personnel should perform the following procedures if they do not endanger personnel or equipment:

- Use an onsite fire extinguisher to control or extinguish any small, localized fires
- Remove or isolate flammable or other hazardous materials that may contribute to fires

- Designate personnel to direct the volunteer fire department or emergency response team
- Warn all occupants of any burning buildings to immediately evacuate
- Close windows, skylights, and doors to any burning buildings but do not lock

5.5.2. Injuries, Fire, or Medical Emergencies

In the event of an injury, fire, or medical emergency, qualified personnel should provide first aid, if required, and should contact the local volunteer fire department or emergency response team for assistance by dialing 911 on the telephone. In general, injured persons should not be moved except by medical emergency response personnel. However, *if* it is clearly safe to do so and will prevent no further injury, on-site personnel may transport injured persons to the nearest hospital.

UXO-related injuries may include traumatic amputation, bleeding, burns, concussion, shock, and death. If personnel are injured as a result of any emergency, UXO-related or otherwise, those personnel should be treated in accordance with emergency first-aid procedures until qualified medical help arrives on site.

If a chemical brought on site by a contractor causes the injury, personnel should use the first aid procedures outlined in the material safety data sheet for the chemical. Other chemical injuries are not anticipated.

6. ENVIRONMENTAL MONITORING

The field team leader will observe personnel for signs of temperature stress and will monitor weather conditions during all field activities to ensure the safety and health of personnel as well as site visitors.

6.1. Temperature and Stress Protection Program

Heat and cold stress are serious conditions that may be encountered during fieldwork. The likelihood of a temperature-related illness depends on factors such as level of physical activity, clothing, wind, humidity, working and living conditions, and an individual's age and state of health. Although OSHA does not have regulations to limit temperature exposures, personnel working on this project will follow guidelines from the American Red Cross and the American Conference of Governmental Industrial Hygienists. This section discusses heat and cold stress and presents temperature stress guidelines.

Temperature stress will be reduced by using engineering controls, safe work practices, and management techniques. Field personnel will have been trained to recognize and respond to temperature-related illnesses as part of OSHA refresher training, cardiopulmonary resuscitation training and first aid training. Field workers should monitor themselves and coworkers for signs of temperature-related illnesses. The field team leader is responsible for initiating rest schedules during fieldwork.

6.1.1. Heat Stress

The possibility of a heat-related injury during fieldwork is high, because some types of PPE increase the body's workload and decrease the body's means of cooling. Heat stress symptoms include heat cramps, heat exhaustion, and heat stroke. Heat stroke is the most serious condition and can be life-threatening. Control actions and rest schedules that may be used to prevent heat stress are provided below.

Depending on the degree and nature of possible heat stress, the field team leader will choose from the following heat stress control actions:

- Provide adequate liquids to replace lost body fluids. These liquids may be water, powdered commercial rehydrating mixes combined with water, or rehydrating commercial liquids (such as Gatorade®).
- Establish a work regimen that will provide adequate rest periods for cooling down. This action may require additional work shifts or earlier or later work schedules to avoid midday heat.
- Require the removal of impermeable protective garments during rest periods
- Ensure that all rest periods are taken in a shaded rest area, if possible
- Regulate rest periods and ensure that workers will not be assigned other tasks during rest periods

- Notify all workers of health hazards and the importance of adequate rest, acclimatization, and proper diet
- Instruct workers how to recognize heat stress and to conduct first aid to prevent heat stress

SKY will use physiological monitoring to evaluate each individual's response to heat stress when ambient temperatures exceed 70 °F and impermeable garments are worn. Higher heat exposures than those shown above are permissible if workers have been undergoing on-site medical surveillance and if it has been established that they are more tolerant of hot weather work than average workers. Workers should not be permitted to continue work when deep body temperatures exceed 100.4°F as determined through on-site medical surveillance.

All persons working at the installation should be acclimatized to local ambient temperature extremes before conducting heavy work. Personnel will be required to slow their work pace as ambient temperatures rise. Field personnel should increase their salt or electrolyte intake at meals to help prevent heat-related injuries.

Solar heat load and glare from sunlight are also major concerns. Adequate skin covering will be required and may include long-sleeved shirts, trousers, hats, sunglasses, and sun block on exposed skin surfaces. Clothing must be light and loose to allow for air circulation and cooling.

Personnel should memorize and learn to recognize the following heat-related injuries:

- Heat cramps. Primary symptom is cramping of muscles. Victims should rest in the shade and rehydrate until the symptom passes. Victims may wish to ingest salt to help the symptom pass.
- Heat exhaustion. Symptoms include normal to slightly high body temperature, increased sweating, pale skin, dizziness, and fast pulse. Victims should rest in the shade and rehydrate until symptoms pass, then perform only light duty activities for the remainder of the work day.
- Heat stroke. Symptoms include high to extremely high body temperature and hot, red, and usually dry skin. Without immediate medical attention, victims may lapse into a coma and possibly die. Medical attention should be sought immediately. Unaffected site personnel should immediately cool victims by any means available. Victims should be moved quickly to any nearby air-conditioned area. Victim's clothing should be soaked in water. The victim should be fanned with a towel or other object to provide air movement.

6.1.2. Cold Stress

Examples of cold-related injuries include frostbite and hypothermia. Susceptibility to these injuries increases with increasing wind speed, wet conditions, and lack of insulated clothing. This section provides control actions and guidelines for cold working conditions.

Cold stress may be of particular concern when a wind-chill adjusted temperature of 10 °F or less is expected. Personnel working outdoors in temperatures at or below freezing may be frostbitten. Working in extreme cold even for a short time may cause severe injury to the body surface or may result in profound generalized cooling, causing hypothermia and possibly death. Areas of

the body that have a high surface area-to-volume ratio, such as ears, fingers, and toes, are most susceptible to frostbite.

Ambient temperatures and wind velocity influence the development of a cold injury. Wind chill (the chilling effect of moving air) should be taken into consideration along with the air temperature when determining whether or not outdoors work is safe.

When chemical-resistant equipment is removed and the clothing underneath is soaked with perspiration, the body cools very rapidly. Workers should therefore avoid removing equipment until they are in a warm area. Thermal socks, long cotton or thermal underwear, hard-hat liners, and other cold-weather gear can help prevent hypothermia. Blankets, warm drinks (other than caffeinated coffee), and warm rest areas are essential to preventing cold-related injury.

Local body injury from exposure to cold is included in the generic term “frostbite.” Frostbite symptoms can be categorized according to the following degrees of severity:

- Frostnip or initial frostbite is characterized by sudden blanching or whitening of the skin
- Superficial frostbite causes the skin to have a waxy appearance and to be firm to the touch while the tissue underneath is resilient
- Deep frostbite causes the skin to be cold, pale, and solid. This degree of frostbite is extremely serious
- Systemic hypothermia manifests itself in five stages of symptoms, including: (1) shivering; (2) apathy, listlessness, sleepiness, and sometimes rapid cooling of the body to less than 95 °F; (3) unconsciousness, glassy eyes, and slow respiration and pulse; (4) freezing of the extremities; and (5) death.
- Trench foot or immersion foot occurs when feet are kept cold and/or wet for an extended period of time. Feet become pale, cold, and possibly pulse-less. During recovery, feet become red, hot, and swollen from excessive blood flow. Trench foot is generally contracted in freezing temperatures (32 °F or less), while immersion foot is contracted at non-freezing temps, generally below 50 °F.

6.2. Meteorological Monitoring

The field team leader will note the wind direction, general weather conditions, and temperature each day. In addition, weather conditions will be monitored at the site trailer and important information will be relayed via two-way radios.

Field operations during summer can create a variety of hazards. Heat cramps, heat exhaustion, and heat stroke, if not remedied, can threaten health or life. Fieldwork during the winter can also cause health hazards, including hypothermia and frostbite. Therefore, as part of the initial site safety, health, and emergency briefing, personnel will be reminded of the symptoms of these conditions and the appropriate remedial actions. In addition, meteorological conditions of concern include thunderstorms, hail, high winds, heavy rains, and the possibility of tornadoes.

7. ACCIDENT PREVENTION PLAN AND REPORTING

Personnel should immediately report all accidents or incidents to the field team leader. The field team leader will immediately ensure that necessary first aid and corrective actions have begun and, if necessary, that emergency agencies have been called. The field team leader will notify the site manager (if applicable) about the accident.

8. SITE SPECIFIC INFORMATION

8.1. Former Kirtland Precision Bombing Range and Isleta Pueblo

8.1.1. Site Description and Survey Location

The Former KPBR is a WWII-era former military training facility located about 10 miles west of Albuquerque, New Mexico (Figure 2). Within the 15,246 acre FUDS, the 3,400 demonstration plan sub-area encompasses at least three documented bombing targets, a suspected target, and possible MEC contamination from a fourth bombing target (Figure 3). For the current demonstration, SKY will fly the MARS CT SW over up to 3,400 acres configured to encompass known and suspected target zones within the 6,500 acre study area.

Isleta Pueblo is located in Bernalillo County, New Mexico, approximately 13 miles south of Albuquerque (Figure 4). It is the largest of the 19 pueblos situated within the Rio Grande Valley, and was initially established in the 1300s. It is bordered on the north by the Sandia Military Reservation, which includes Kirtland Air Force Base (adjacent to Former KPBR), the Manzano Mountains on the east, and the Rio Puerco (a tributary to the Rio Grande) and Laguna Pueblo Reservation on the west. As well as the main pueblo, Isleta comprises the small communities of Oraibi and Chicale. The name “Isleta” is Spanish for “little island,” referring to the fact that when the Spaniards first arrived, the Pueblo was literally on an island, with the Rio Grande curving on each side. The Native American residents of the pueblo are from the Tiwa ethnic group.

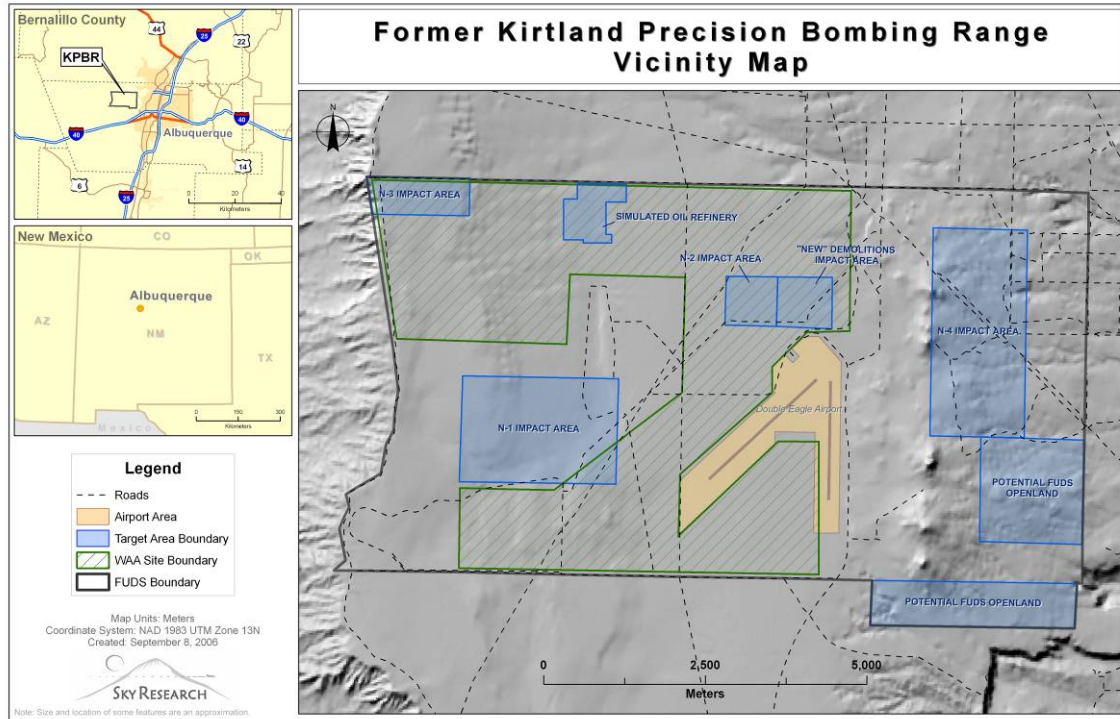


Figure 2. Former Kirtland Precision Bombing Range WAA demonstration area.

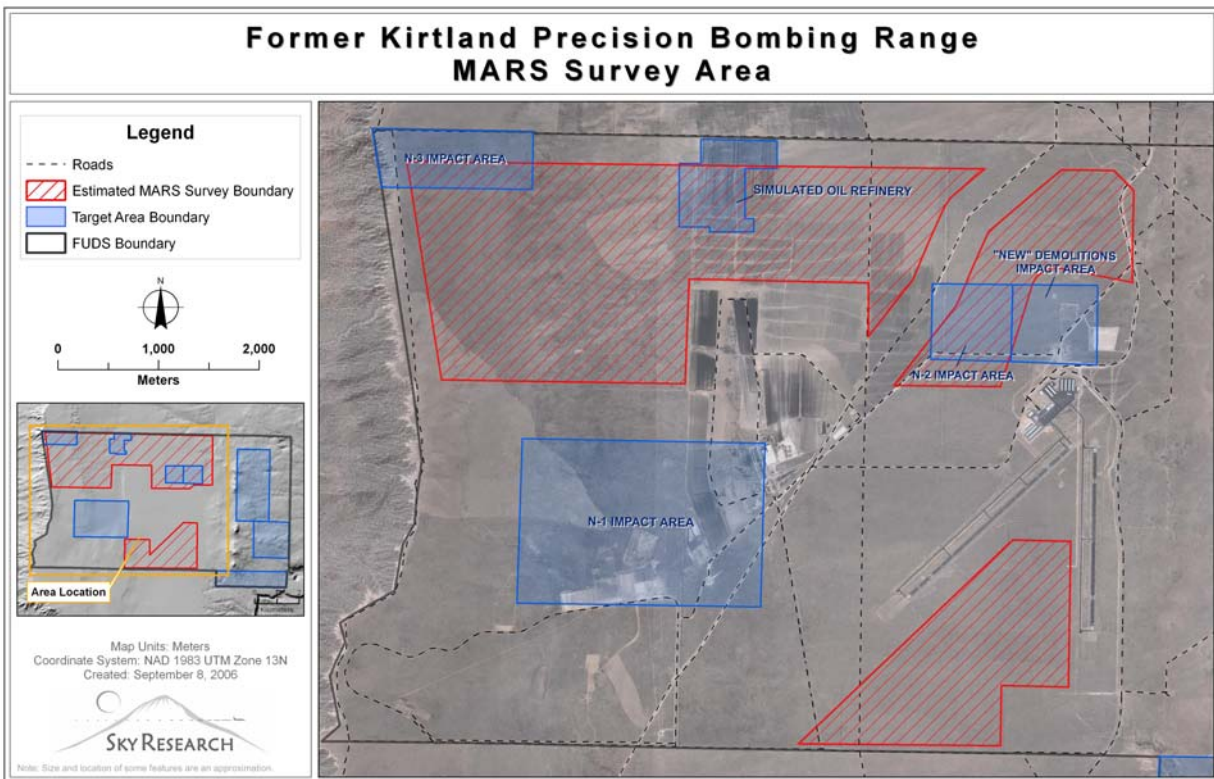


Figure 3. MARS survey area at Former KPBR.

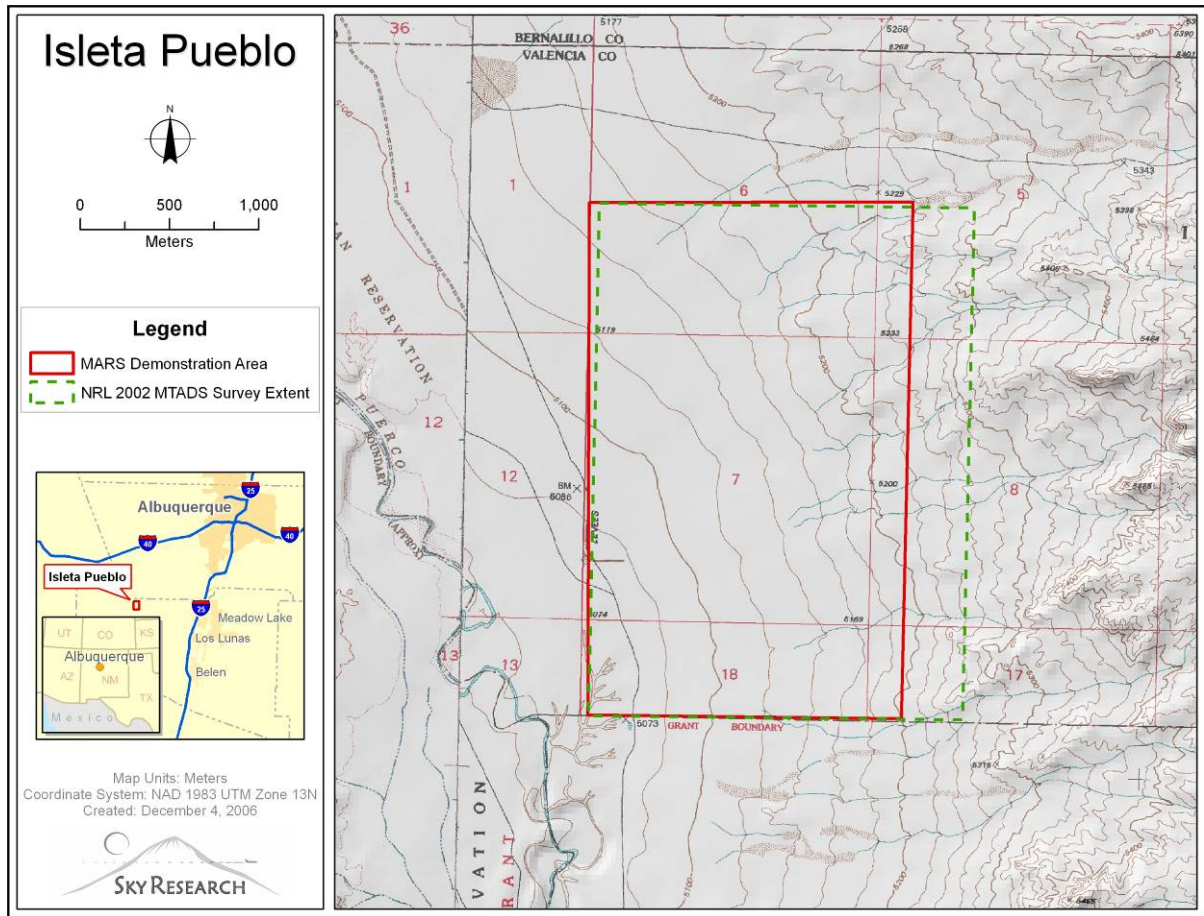


Figure 4. Isleta Pueblo MARS demonstration survey location.

8.1.2. Past, Current and Future Use

Please refer to the ESTCP Program Office WAA Pilot Program Health and Safety Plan and the Sky Research Demonstration Plan for more information on the past, current and future use of the sites.

8.1.3. Base Operations

The aircraft and crew will be based and refuel out of Double Eagle Airport, directly adjacent to the Kirtland site and approximately 15 nautical miles from the Isleta Pueblo site.

8.1.4. Estimated Survey Schedule

See Table 7 in the Demonstration Plan

8.1.5. Local Emergency Information

Local emergency services contact information is provided in Table 2.

Table 2. Emergency Contact Numbers for Former KPBR and Isleta Pueblo

Emergency Service	Emergency Number	Non-emergency Number	Location
Albuquerque Police Dept.	911	(505) 768-2200	400 Roma NW Albuquerque, NM 87102
Ambulance	911		
Albuquerque Fire Dept	911	(505) 833-7300	11510 Sunset Gardens, SW Albuquerque, NM 87121
Albuquerque Care Center	911	(505) 242-4116	239 Elm St NE Albuquerque, NM 87102
Highland Pharmacy		(505) 243-3777	717 Encino Pl NE Ste 12 Albuquerque, NM 87102